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ORIGINAL ARTICLES.

The Igneous Rock at Hestercombe, Somerset.

By E. D. Evens, B.Sc., and F. S. Wallis, Ph.D.

(PLATE XI.)

I. Introduction and Previous Work.
II. Description of Exposures and Field Relationships.
III. Petrography.
IV. Conclusions.

I. Introduction and Previous Work.

THE object of this investigation was to examine the well-known Hestercombe "syenite" in greater detail than had been done before, to attempt to trace its extent, and if possible, to determine its age.

The rock was first noticed by Leonard Horner [1] who describes it as a vein of granite which has altered the slates immediately in contact. At that time, this altered rock was quarried as a whetstone, which enabled him to examine and describe the junction, and he mentions that the granite is locally known as "Pottle Stone".

The Rev. D. Williams [2] also examined the rock and traced it from the main Hestercombe Quarry westwards for about 3½ furlongs.

J. H. Payne [3] does not add anything of importance to the preceding account, but gives a section (by J. D. Pring) showing the "syenite" as a "dyke or vein" parallel to the bedding in "quartzose schists". W. A. E. Ussher [4] refers to it and gives a petrographical description by Dr. Flett, who considers the rock to be diorite.

Mr. Inkerman Rogers [5] describes the rock as continuous with the Bittadon felsite and in a direct line with it. He mentions tracing

[1] *Trans. Geol. Soc.*, Ser. 1, vol. iii (1816), pp. 348, 349.
[2] *Q.J.G.S.*, vol. ii (1846), pp. 68, 69.
[3] *Proc. Som. Arch. and N.H. Soc.*, vol. v, pt. ii, for 1854 (1855), pp. 102, 103.
[4] *Mem. Geol. Surv.*, "Quantock Hills" (1908), pp. 28, 29.
[5] *Trans. Devon Assoc.*, vol. lviii (1926), p. 231.

it from Hestercombe to Coombe Quarry and from thence nearly to the main Taunton-Bridgwater road.

The main quarry has been visited on at least three occasions by various societies.[1] [2] [3] Very short mention is also made of the rock by H. T. de la Beche,[4] W. Buckland,[5] and W. Baker.[6]

The rock occurs on the south-eastern edge of the anticlinal uplift of the Quantock Hills, about 3 miles north of Taunton. It has been traced over a distance of about 5 miles in an east and west direction from Coombe to Tetton Farm, Kingston, the well-known quarry about ⅓ mile north of Hestercombe House occurring approximately midway between these two places. The exposures at Coombe are on the 200 foot contour line, from whence they climb to 400 feet at Hestercombe, maintaining this level until they vanish just beyond Kingston.

The geology of the district is well described by Ussher,[7] who regards the country rock as belonging to the Morte Series of the Devonian system, which here consists of much folded and highly quartz-veined slates and grits. These beds generally dip southwards at angles varying between 20° and 45°. The western exposures occur near the junction with the Trias and a portion of the igneous rock may possibly be concealed by this covering.

Map references.

1 in. Geol. Survey. Sheet 295 Taunton (new series). 1907.
6 in. O.S. Somerset. Sheets LX S.E. and LXI S.W.

II. Description of Exposures and Field Relationships.

The main exposure occurs in an unworked quarry situated on the western side of Hestercombe (VI),[8] a small, picturesque, well-wooded valley running northwards from Hestercombe House. It shows by far the largest outcrop of the rock to be seen in situ and has an approximate height of 36 feet and a width of 54 feet. The mass is remarkably homogeneous and a series of specimens taken at intervals across the quarry in a horizontal line showed an unweathered rock with practically no variation. No actual contact with the slate was seen. There are three sets of inclined joints; the main series dips approximately 30° S., while the other sets are almost vertical, one striking east and west and the third north-east and south-west. In some parts of the quarry there appears to be a slight vertical schistosity.

[1] *Proc. Som. Arch. and N.H. Soc.*, vol. xviii for 1872 (1874), pp. 33, 34.
[2] *Proc. Geol. Assoc.*, vol. xxii (1911), p. 254.
[3] *Proc. S.W.N.U.*, vol. i, pt. ii (1925), pp. 42 and 43.
[4] *Rep. on the Geol. of Cornwall, Devon, and W. Somerset* (1839), pp. 186, 187.
[5] *Proc. Som. Arch. and N.H. Soc.*, vol. i, pt. i for 1849 (1851), p. 18.
[6] Ibid., pt. ii, pp. 127, 128.
[7] *Mem. Geol. Surv.*, "Quantock Hills" (1908), pp. 25, 26.
[8] Roman numerals refer to numbers on map.

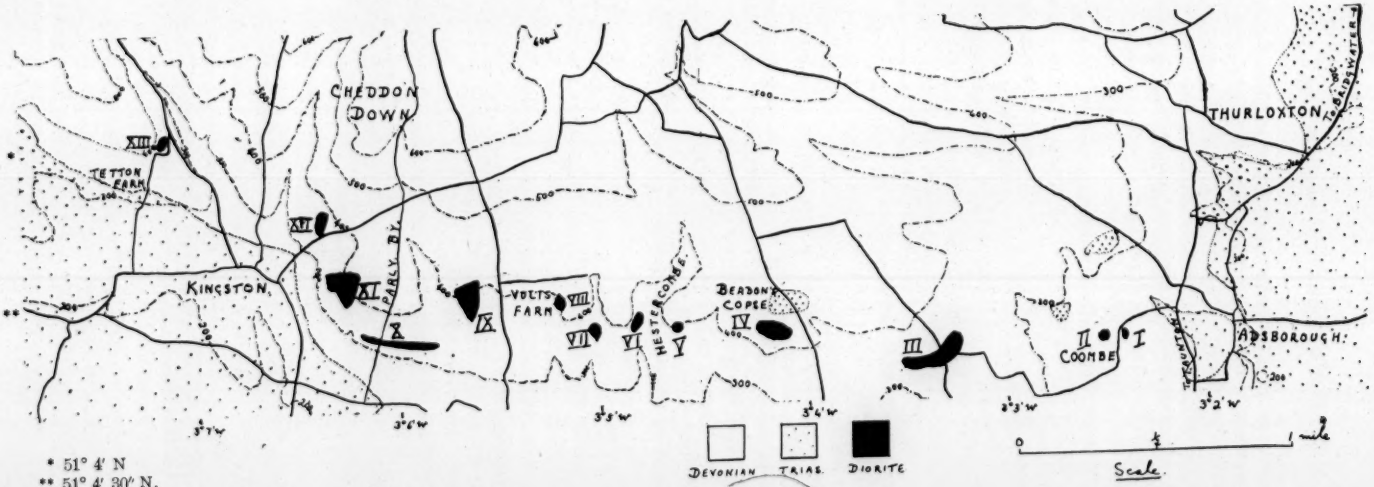


FIG. 1.—Map showing outcrops of Diorite.

Careful search on the eastern side of the valley and also north of the quarry failed to produce any evidence of the extension of the rock in these directions. Southwards, however, it can be traced by loose pieces along the western slope of the combe as far as another quarry (VI) (termed Whetstone Quarry by previous authors). This is opened in normal Devonian slate and the intrusion forms a small mass in its north-eastern corner, and is of a somewhat coarser-grained variety than the main mass. The junction with the slate can be traced along an oblique line across the quarry face and in some cases the igneous rock is in actual contact with the altered and hardened slate, whilst in others an ill-defined band, some 12 inches thick, separates the two. This band appears to consist of an intermingled mass of the intrusion and small pieces of slate, the whole being riddled with veins of silica and iron oxide. The exposure is probably the cross section of a vein with slate above and below.

Another important exposure occurs at Coombe (west) Quarry (II) near Adsborough. At the time this was visited (1928) the general structure was that of an anticline whose axis pitched ESE. Along the central portion of this anticline, where the beds were much disturbed and broken, a sill (4 feet thick) had been injected and it had thrown off veins (1 feet thick) across the bedding planes. Owing to the irregular manner in which the quarry had been worked these veins occurred as isolated patches whose connection with the main body was difficult to trace. They were of small extent and the writers were informed by the foreman that they continually die out and are replaced by others as the quarry face is worked back. The slate was altered in some places to a silvery schistose rock for a distance of about 12 inches, whilst in other places it was only hardened and the actual junction was very sharp. This alteration is shown both above and below the vein, thus proving the rock to be intrusive. As the thermal metamorphism has caused an increased development of mica in the slate parallel to the cleavage planes, which are thus accentuated, and has converted it into a silvery phyllite, it follows that the intrusion must be of later date than the cleavage although the interval between the two may have been short.

It has been detected in a wood (1) due east of Coombe Quarry on the other side of the valley, but no trace of the rock was observable in the large Coombe (east) Quarry.

It was also found in situ at VII in the northern wall of an overgrown slate quarry occurring as a thin vein of a finer grain than usual. This exposure marks the limit of the westward extension of the outcrop as defined by Williams.[1] The rock also occurs scattered about on the surface on both sides of the small valley, immediately to the north of this quarry.

The presence of outcrops at III to V and VIII to XIII (inclusive) was indicated by means of loose pieces found chiefly on the surfaces

[1] *Q.J.G.S.*, vol. ii (1846), p. 68.

of ploughed fields, nothing in situ being visible. Macroscopically the rock at all these points was remarkably close in general appearance to that of the main quarry (VI) except that, as might be expected, it was somewhat more weathered. The only variation worth mentioning was found where the parliamentary boundary crosses exposure X, the weathered material there being nearly black.

The rock was also found as pebbles and blocks of varying sizes in red sandy loam of Triassic age, exposed in an old sand pit in Beadon's Copse (about ½ mile due east of Hestercombe). The fragments were unweathered and occurred abundantly near the base of the steep bank about 10 feet high, which formed the southern side of the excavation.

III. Petrography.

In hand specimens the "syenite" appears as a medium-grained rock, pink and speckled with greenish-black spots when fresh, but becoming brown and occasionally quite black when weathered. The specific gravity is 2·68.

The felspar, which gives the dominant colour, varies from pink to yellowish-brown, and the individual crystals are distinguishable with a pocket lens. It is abundant, the ferro-magnesian minerals being present in much smaller quantities and usually aggregated into greenish-black spots of indefinite outline.

In thin section the structure is generally granitic. The felspars, which are fairly fresh, are lath-shaped, uniform in size, and form the bulk of the rock; in some cases, e.g. at Coombe, they occur as larger separate crystals set in a ground mass of smaller laths, the structure approaching porphyritic. In other cases, also at Coombe, the crystals are more ragged in outline and in a few instances are grouped as radiating clusters which give a black cross effect with polarized light. Many of the laths are bent, a feature well seen at Hestercombe but less noticeable at Coombe. The majority show lamellar twinning and in suitable sections, symmetrical extinctions up to 18° can be obtained, indicating a plagioclase of composition between oligoclase and andesine; and this is confirmed by the refractive index which is close to that of quartz. A certain amount of untwinned felspar is also present.

The ferro-magnesian minerals are nearly completely decomposed and generally occur as aggregates filling in the interstices between the felspar laths, but are more abundant and rather fresher at Hestercombe than at Coombe. When present in very small quantities they surround them as a thin film only. A large proportion was originally biotite and at the Whetstone Quarry (VI) pleochroic haloes may still be seen. The other ferro-magnesian minerals now occur mainly as brownish-green chlorite (mixed with leucoxene after ilmenite) and are sometimes arranged in fan-shaped groups, but good pseudomorphs are seldom visible. However, a few eight-sided forms are present which appear to be cross sections of enstatite

(partially decomposed to bastite) and one showed a crystal angle of 113°.

Secondary white mica associated with quartz occurs as a speckly decomposition product showing high polarization colours and also alone in large fan-shaped aggregates.

Quartz is present as an interlocking mosaic with indefinite outlines, crowded with inclusions and with a certain amount of interstitial chlorite, and also as large individual grains, which appear to be primary; these were more abundant in the rock from Coombe than in that from Hestercombe, and some show strain shadows and others inclusion of vermicular chlorite.[1]

Amongst the accessory minerals, apatite occurs in several forms :—

(*a*) Small granules in the felspar.
(*b*) Long and slender needles passing through several crystals.
(*c*) Short and stumpy forms.

A little nearly colourless epidote is present in irregular grains.

Considered as a whole, the rock is very uniform and the sum total of variations is small, the most important one being an increase in quartz content from west to east.

It would appear, therefore, that the rock at Hestercombe is a diorite, but the greater proportion of quartz at Coombe justifies the name of quartz-diorite for this latter rock.

The alteration of the Devonian slate by the heat of the intrusion is in all cases small. At a distance of 12 inches from a sharp junction in the Whetstone Quarry (VI) the slate is hardened and the cleavage tends to be obliterated. In Coombe Quarry, however, the slate sometimes becomes silvery near the intrusions and the cleavage is intensified. In thin sections these altered slates are not very different from the normal variety but the texture is slightly coarser and white and brown mica are more strongly developed. A yellowish, nearly isotropic, indeterminable substance occurs, giving a faint dappled polarization.[2] Thin sections of a sharp junction were examined and the decrease in size of grain as the contact with the slate was approached was evident even within the limits of a single slide. The junction is often highly silicified and much chlorite is present.

IV. Conclusions.

The rock is thus definitely of an intrusive character. It has a dyke-like appearance at Hestercombe but shows a sill structure at Coombe.

The mode of occurrence in the field and the small variation shown throughout the five miles separating the extreme exposures indicate that they all form one connected whole, and are off-shoots from a larger mass underlying the area. Diorites are rare in England and

[1] *Q.J.G.S.*, vol. lxxiii for 1927 (1928), p. 773.
[2] Compare Hutchings, W. M., Geol. Mag. (1894), pp. 44, 45.

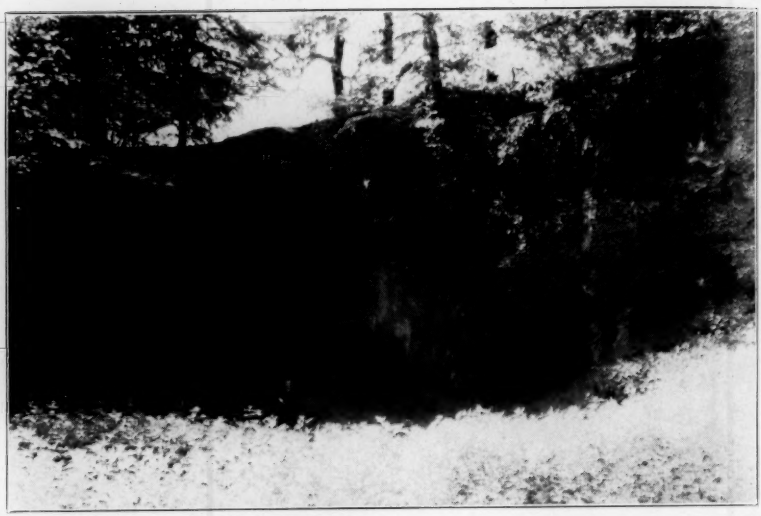


FIG. 1.—HESTERCOMBE QUARRY.

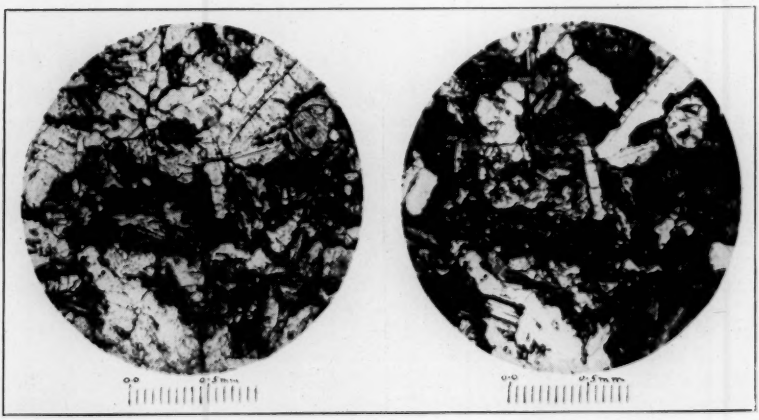


FIG. 2. FIG. 3.

Photo, E. D. E.

THIN SECTIONS OF DIORITE, HESTERCOMBE.

this example shows no point of close resemblance with other igneous rocks in the western counties.

Regarding the age of this intrusion a limit in one direction may be deduced from the fact that in some cases the cleavage of the slate has been accentuated by the heat of the molten material, while the presence of fragments of the rock in Triassic deposits determines the other. As the folding of the Quantock range is now generally regarded as being of Armorican age, it seems probable that the intrusion was connected with the closing movements of that period.

Since the large granitic masses of Devon and Cornwall are also referred to the same era it may be that this intrusion is connected with them, and is to be regarded as a marginal modification of the Dartmoor granite.

The authors wish to express their best thanks to the Hon. Mrs. C. M. Portman for her kindness in giving them permission to examine the exposures in her grounds; to Dr. H. H. Thomas for the loan of slides and to Dr. H. Bolton for his interest in the work. The research was carried out by means of a grant from the University of Bristol Colston Research Fund, kindly allocated by Professor S. H. Reynolds.

EXPLANATION OF PLATE XI.

FIG.

1.—Hestercombe Quarry. The diorite forms the whole of the rock face.

2.—Diorite, Hestercombe Quarry. × 20. Ordinary light. 2 in. objective. The lighter portions are composed of felspar, whilst the irregular darker patches are decomposed ferro-magnesian minerals. The mineral in the upper left hand portion showing good crystal outline is a pseudomorph after enstatite.

3.—Do. Crossed nicols. The same field as FIG. 2.

The Manchioneal Beds of Jamaica.

By C. T. TRECHMANN, D.Sc., F.G.S.

(PLATES XII AND XIII.)

INTRODUCTION.

ONE of the first features that will probably strike a geological observer in Jamaica is the extent and thickness of the great covering series of White Limestones. This series, which as Sawkins wrote in 1865, cannot be less than 2,000 feet in thickness, impresses one with the evident magnitude of the duration of the Tertiary period; especially when one reflects that it represents only a portion of the Tertiary, probably inclusively from the Upper Eocene to the Lower Miocene. Equally formidable though less conspicuous thicknesses of early Tertiary beds which underlie the White Limestones, namely, the Yellow Limestones and the Richmond beds or Carbonaceous Shale, represent the middle and basal Eocene.

Well on in the Miocene period this great series of White Limestone and other beds of Jamaica was raised up more or less in the form of an elongated dome stretching in an east and west direction. This uplift caused, as one may see in many sections, a great deal of splintering, powdering, and crushing of the hard and unyielding beds of the White Limestone.

The remaining beds, subsequent in age to the Middle Miocene, are mainly marginal, and have for the most part been formed from the degradation of the older beds after they were elevated and comprise a series of limestones, marls, and conglomerates. It cannot be said that the boundaries of the various divisions of these later beds have been at all clearly defined or mapped. Some of them are white marls which in some sections seem to pass gradually down into the crushed beds of the White Limestone; others, such as the conglomerates that overlie the Bowden shell beds near Port Morant, have evidently been formed from the degradation of Cretaceous and basal Eocene conglomerates of the Blue Mountain series.

The present paper deals with a group of the newer marginal beds comprising the Manchioneal beds of R. T. Hill and probably some part of the Pteropod Marls of L. Barrett and J. G. Sawkins. They are evidently the newest Tertiary beds which underlie the recently raised Coral Rock or Coast Limestone as Sawkins calls it. The Coral Rock in the Port Antonio and other areas, however, does not follow immediately or conformably on the Manchioneal beds but is banked up against, and deposited on, an eroded platform of the Manchioneal Marls. Near Port Morant extensive buff-coloured marls having the general character of the Manchioneal beds are apparently later than the Bowden beds of that area, though I could not find a section where the superposition is clearly shown.

The Bowden beds, whose numerous fossil shells are the best preserved in Jamaica, are now regarded as Middle Miocene (Vindobonian)[1] in age. The type locality of the Bowden fossils is at the south-east end of Jamaica. Sawkins, however, on page 163, speaks of Bowden fossils at Round Hill west of Milk River, on the middle of the south coast of Jamaica, a reported occurrence that needs confirmation.

The Manchioneal beds, on the other hand, have a comparatively meagre and poorly preserved fauna, and so far as they are typically developed, are restricted to the eastern end of the island but have apparently a more extensive areal distribution than the Bowden beds. It would appear that the Manchioneal beds were originally laid down as a more or less continuous marginal fringe round the eastern end, that is to say around the more elevated portion of Jamaica. If this is the case the Manchioneal beds have been

[1] W. P. Woodring, *Miocene Mollusks from Bowden, Jamaica*, part ii, p. 108. The Carnegie Institute of Washington, Nov., 1928.

appreciably raised and tilted, and the various remaining exposures isolated from one another by denudation since their elevation.

Unlike those of Barbados, Cuba, and some other West Indian Islands, the coral reefs of Jamaica seem to have been raised only to a moderate degree. At the eastern end of the island the recently uplifted coast limestone seems to go up only to a height of about 25 feet. Towards the western end of Jamaica, however, older coral reefs, generally with a very poorly preserved fauna, appear in the Montego Bay and other areas to have been elevated to about 75 feet. Some of these older and very much rotted beds of coral rock pass gradually into white and yellow marls and may correspond in age to the more typical Manchioneal beds of the eastern end of the island.

The typical Manchioneal beds of the north and east coast of Jamaica which stretch intermittently from Buff Bay to the mouth of the Plantain Garden River form, therefore, a series of somewhat

FIG. 1.—Locality sketch-map of Jamaica.

exceptional interest palaeontologically and lithologically and seem to represent a phase of deposition in rather deep bays around the coast.

It is not easy to understand precisely which beds were included under the term Pteropod Marls by Barrett and Sawkins. Robert Etheridge, F.G.S., in his appendix to Sawkins, page 313, writes: "The column headed Pteropod marl has reference to a peculiar deposit apparently of recent age; three genera of Pteropoda occur in it and give name to the marl; 16 species of recent marine mollusca belonging to the surrounding seas have been obtained from this marl." In his table of Jamaican fossils three species of Brachiopoda are mentioned, and many of mollusca, but no Pteropoda are referred to. Further on he speaks of the Pteropod marl as the same as the White Marl, and still further he speaks of Pteropod marls or deep sea marls as having been elevated 600–1,000 feet above their original place. From this it would seem that some of

the chalky marls of the White Limestone series were included in this term. I did not find any Pteropoda in the Manchioneal beds; but Woodring, in his monograph on the Bowden fauna, records several species of Cavolinia and one of Diacria among those fossils. It seems that Pteropoda may occur in any of the more recent formations in Jamaica.

R. T. Hill [1] originated the name Manchioneal beds and pointed out that the coastal beds at the extreme eastern end of Jamaica, which are coloured green on Sawkins's map as indicating Yellow Limestone, lie in reality above the great mass of White Limestone and not below it. Unfortunately the usefulness of this observation was marred by the complication he introduced into Jamaican stratigraphy by confusing together the Cretaceous and Yellow Limestones (Eocene) in the Rio Grande Valley and calling it the Cambridge formation and mapping wide areas as such.

Hill places the Manchioneal formation below the Kingston formation, the extensive spread of flood plain gravels of the Liguanea area upon which the town of Kingston stands. He refers to these gravels as nearly allied by position to the age of the Manchioneal beds which he considers Pliocene (page 90). The Liguanea gravels, unfortunately unfossiliferous, seem to me to be much more recent than Pliocene. Again (on page 86) Hill refers to the Manchioneal formation as occurring at Mulatto Bay and Manchioneal, and on page 84 he correlates the beds at Navy Island with the Bowden Beds of Duncan and Wall. It will thus be seen that the correlation of the later Jamaican beds is by no means quite clear.

Description of Localities.

Port Morant (*South-East Coast*).

To the west of Port Morant Harbour a road cutting exposes about 30 feet of grey and buff-coloured thinly bedded marls with intercalations of harder calcareous beds which apparently belong to the Manchioneal series. The lines of irregular chalky concretions are apparent, but fossils are scarce although fragmentary oysters occur. The beds dip slightly to the south-east. Similar beds occur also on the east side of Port Morant Bay to the south of Bowden, and seem to overlie the Bowden shelly gravels in this area, but to show the actual relationship the district should be mapped in greater detail.

Amity Hall (*East Coast*).

Between this place and Hector's River there are exposures 15 or 20 feet thick of rubbly coralline limestones resting upon the White Limestone, containing a fair number of fossils mostly of

[1] "Geol. and Phys. Geogr. of Jamaica," *Bull. of Mus. Comp. Zool. Harvard*, vol. xxxiv, 1899. Appendix by T. Wayland Vaughan.

recent aspect. I thought they might represent a more coralline or less marly facies of the Manchioneal beds, but the exposure seems to be an early coral-rock of Plio-Pleistocene age. The fossils collected there are the following :—

Arca occidentalis Phil.
Pectunculus cf. *pennaceus* Lk.
Chione cancellata Linn.
Scapharca cf. *nux* Sow.
Columbella mercatoria Linn.
Patella sp.
Bul'a striata Brug.
Strombus gigas Linn (spines of).
Cerithium litteratum Born.
Vermetus sp.
Conus cf. *pygmaeus* Rve.

Innes Bay and White River (East Coast).

South of and around this bay the Manchioneal beds seem to cover a considerable area and to have been elevated to about 150 feet above sea-level and are well exposed in sea cliffs and road cuttings. In the cuttings there are sections of about 50 feet of broken-up marly limestones intercalated with thin bands of white and pink marl and lines of soft chalky concretions. Here and there a mass of very much rotted and dissolved coral occurs. Fossils are scarce and are generally present as poorly preserved casts, but occasionally a Terebratula or other Brachiopod with the shell preserved occurs. *Terebratulina caput-serpentis* was found here. Towards the sea-coast the Manchioneal beds are overlain by raised coral rock forming the sea-cliffs, which are about 25 feet high.

Manchioneal Harbour (East Coast).

This small and historic but now neglected bay offers probably the best section of the Manchioneal beds. The headlands to the north and south of the harbour entrance are formed of raised coral rock resting up against and upon the Manchioneal beds. The breaking through of this barrier of coral rock and erosion of the soft marls seems to have formed the harbour in this place, as it has at Port Antonio and other localities.

Immediately to the north and south of the village the Manchioneal beds are well exposed and consist of about 60 feet of calcareous rubbly nodular pink and white thinly bedded marls with here and there a rounded pebble derived from the White Limestone. Fossils are scarce in the lower 15 feet or so, but are very profuse rather higher up and comprise mostly small species in the form of casts. *Terebratulae* with the shell preserved are rather plentiful in the lower beds, and *Ianthina* (a rare shell to find fossilized) can be collected, together with *Cypraea*, *Pecten*, *Spondylus*, and other genera.

Port Antonio (North-East Coast).

The harbour of Port Antonio consists of a wide, roughly semicircular bay, in which there is an island called Navy Island, and to the south-east of this a peninsula on which the Titchfield Hotel of the United Fruit Company stands. The peninsula is joined to the mainland by a low-lying neck of silt and sand, which if it were washed away or submerged would make it an island similar in structure to Navy Island. The seaward edge of both Navy Island, the Titchfield Promontory, and the mainland to the east called Folly Point is made of raised coral rock. It is evident that the harbour of Port Antonio has been formed by the sea breaking through this wall or rampart of raised coral rock and washing out the lower and softer beds of the Manchioneal series up to the line where the White Limestone and older rocks commence to rise up to form the foothills of the Blue Mountain Massif. Navy Island, the Titchfield Peninsula, and Folly Point on the east side of the harbour afford excellent sections of the Manchioneal beds.

Navy Island, Port Antonio.

The north-facing coast of Navy Island shows a specially good section of Manchioneal beds. At the seaward corner they sink down and pass under the coral rock or coast limestone which lies on an eroded shelf or platform of the Manchioneal beds. The following section of the beds under discussion was observed in descending order :—

	Thickness in feet.
Pink, grey, and brown clayey nodular calcareous thinly bedded marls dipping slightly to the north-east. Intercalated with these are one or more beds about 5 feet thick of old broken up coral masses, pieces of white limestone, etc. In clayey marl below a bed of broken coral a large specimen of *Spondylus* cf. *chiriquensis* occurred with *Turritella exoleta* var. *jamaicensis*	30
Bed of brown clay with few fossils ; *Natica*, *Dentalium*, etc. .	25
Part of section obscured by slipping of clay and cultivation .	25 (?)
Yellow and brown clays with rough irregular slabs of brown impure crystalline sandy limestone, these beds become thicker lower down till they form a series of limestone beds each 1–2 feet thick, with clay partings between. They dip a few degrees to the north-west, and are well seen opposite the bath house belonging to the hotel. On the surfaces of these slabs I collected, a few years ago, some indifferently preserved specimens of *Ostrea haitensis* and the Foraminiferon *Cuneolina*. The under surfaces of the limestone slabs show casts of wedge—or cup-shaped corals, but these cannot be extracted with any ease. Other fossils are very poorly preserved, but a species of *Pecten* occurs	15
Brown clays with very few fossils, passing under the water of the harbour, towards the south	(?)

Buff Bay (*North-East Coast*).

On the north coast a little to the east of the mouth of the Buff Bay River a road cutting exposes a good section of Manchioneal beds at about 25 feet above sea-level. The exposure is an isolated one of small extent and forms a series of low rounded hills near the sea. The Manchioneal beds rest up against and upon the chalky marls of the White Limestone formation and their material was evidently largely derived from the older beds as rounded lumps of white marl occur here and there in the Manchioneal series. The exposure in the road cutting appears as follows, the beds dipping about 20° to the W.N.W. :—

	Thickness in feet.
Thinly bedded rubbly and clayey limestone bands with beds of soft brown clay between. Corals are plentiful and occur in masses up to a foot in diameter. Mollusca are scarce; *Ostrea folioides*, *Pecten nodosus*, etc.; Echinoderm spines occur	20
Grey, white, and brown marls apparently made up of debris of the chalky white limestone below, and seeming to grade down into that rock. No fossils seen	15 (?)

R. T. Hill (pl. xxvii) gives a photograph of the roadside near Buff Bay, showing the chalky White Limestone upon and against which the above described section of Manchioneal beds rests in the distance. He calls it "Bowden Formation", the name apparently referring to the chalky marls rather than to the shelly Manchioneal beds.

The Low Layton Massif (*North-East Coast*).

To the north-west of Hope Bay, near the coast at Low Layton, there is a massif attaining an altitude of about 750 feet called by Sawkins and others the "Extinct Volcano". This is a series of lava flows of a pillowy nature and was well described by Sawkins (page 120). These lava flows seem to be associated with the white marl of the White Limestone series, but are overlain and surrounded by marls of the Manchioneal character. In a road cutting near by there are about 30 feet of the bedded buff-coloured clays with intercalated layers of small white irregular concretions and small derived pebbles of white limestone. The only fossil I saw was a small *Pecten*.

Montego Bay (*North-West Coast*).

In and around Montego Bay, at the railway station, Brandon Cave, and other localities up to a height of about 75 feet are several exposures of old and rotted coral limestone. These beds are evidently much older than the more recently uplifted coral rock of the present coastal fringe which though much pitted and dissolved contains excellently preserved fossils. The old coral rock seems to pass here and there into white and grey marls which contain few

if any recognizable mollusca. Some of these beds may represent a shallow water equivalent of the more typical Manchioneal beds of eastern Jamaica.

Green Island (*North-West Coast*).

A cutting about 30 feet thick on the north side of the Pell River to the east of Green Island Harbour shows a section of 30–40 feet of yellowish irregularly bedded limestones with marly partings and contains old dissolved coral masses and very poorly preserved mollusca; *Cypraea*, indeterminable bivalves, etc., all in the form of casts. The lines of soft, irregular, chalky concretions which seem to be peculiar to the Manchioneal beds are well seen here, so this exposure may represent the equivalent of those beds.

Description of the Fossils.

Turritella exoleta Linn. var. *jamaicensis* nov. Pl. XII, Figs. 19 and 20.

Description.—Shell rather large, of many whorls increasing gradually in size, sutures well marked, sides of the whorls excavated in the middle. Just below the suture there is a prominent rounded ridge and above the suture a smaller but still prominent rounded ridge with an anterior groove immediately above the suture. The surface of the shell when well preserved, especially in the younger stages, is decorated with very fine thread-like concentric ridges. Growth lines are sinuous, sweep backwards on the concave part of the whorl, and bend strongly forwards anteriorly. The lip is broken.

Dimensions.—Height about 73 mm., diameter of last whorl 19 mm.

Locality.—Navy Island, Port Antonio; and Buff Bay, Manchioneal beds.

Remarks.—This shell resembles and may be ancestral to the recent *T. exoleta*, which is a living West Indian form, though specimens in the British Museum (Sloane collection) are labelled "Guinea". In *T. exoleta* the sutures are weaker, the ridge above and below them seems to merge more into one continuous ridge, and the concave median part of the whorl is successively scooped out, a feature not prominent in the Manchioneal fossil. It also resembles *T. exoleta* var. *limonensis* Ollson from the Gatun stage of Port Limon, Costa Rica.

W. P. Woodring describes and figures *T. guppyi* Cossmann, a Bowden shell which belongs to the group of the recent *T. exoleta*, but is smaller and more strongly noded and sculptured than either *T. exoleta* or the present shell. Woodring, however, remarks that the weakly beaded variety of *T. guppyi* found at Bowden is clearly similar to *T. exoleta*.

Drillia sp. Pl. XII, Fig. 22.

Two whorls of a thin-shelled species of a *Drillia* about 32 mm. high were found at Manchioneal; it is larger than most of the Bowden forms.

Ianthina cf. *communis* Lk. Pl. XII, Fig. 21.

Ianthina is rather common in the lower part of the cliff by the roadside at Manchioneal, but I only secured one specimen with the shell preserved. It is 11 mm. high and 15 mm. in diameter; the spire is obscured by matrix, the suture is fairly well impressed, and the angle of the shell rather rounded. It compares well with but is smaller and may have a lower spire than the familiar living *I. communis* (= *I. fragilis* Lk.), the individuals of which vary appreciably in height and angularity of whorl.

Woodring records a small broken *Ianthina* from Bowden, and says that so far as known this genus is not recorded as a fossil at any other locality in America. His specimen was too small to identify, but "the shell is higher and suture deeper than in the common species usually called *I. communis*, and it is probably a young shell of a species similar to *I. globosa* Swainson".

Recluzia cf. *Hargravesi* Cox. Pl. XII, Fig. 24.

Shell of eight whorls, well separated, sides very well rounded, suture deep and sunken, the spire pointed and tapering. Test very thin, glassy, and smooth on the outside. The first two whorls are smooth, the third and fourth and fifth have an appearance of reticulate ornamentation, though one cannot be sure that this is not due to accident of fossilization in the matrix; last three whorls smooth and growth lines nearly straight. Outer lip simple, inner lip obscured. Height 20 mm., diameter 10·5 mm., the last whorl about as high as the spire.

Locality.—Navy Island, Port Antonio.

This specimen is very like a recent example of *R. hargravesi* Cox in my shell collection localized Port Stephens, New South Wales, Australia. Specimens in the British Museum are, I think, not labelled as to locality. This, together with *Ianthina*, is a pelagic genus, so its locality may not have much significance.

Natica (*Stigmaulax*) *vererugosum* Cossmann. Pl. XII, Fig. 23.

An axially grooved naticoid shell from Navy Island with a deep and wide umbilicus and a strong indented funicle seems to be identical with the above species from Bowden. The umbilicus is not completely exposed in the Manchioneal specimen, but on comparison with figures and actual specimens from Bowden there seems no essential difference. Guppy named the Bowden shell *Natica sulcata* Born.; this is the living and evidently related West Indian form, but Woodring points out the differences between the Bowden and the living shell. The living *Stigmaulax sulcata* is a larger and stronger and more solid shell than is *S. vererugosum*.

Natica (*Naticarius*) cf. *canrena* Linn. var.

A *Natica* resembling a small form common in the Coral Rock of Barbados occurs in the Manchioneal beds at Navy Island. It is

smaller than, but essentially similar to, an abundant Bowden shell figured by Woodring as *Natica* (*naticarius*) *canrena antinacca* Cossmann, a variety of the living *Natica canrena* Linn.

Cypraea cf. *cinerea* Gmel. or Linn. Pl. XII, Fig. 17.

Poorly preserved casts of *Cypraea* from Navy Island, Buff Bay, etc., seem to agree with this living and rather variable species.

Ranella (*Lampadopsis*) cf. *thomae* d'Orb. Pl. XII, Fig. 18.

A fossil with the spire partly eroded agrees in shape and size with this recent form which is reported from Teneriffe, Cape Verd Islands, Mauritius, etc. It is 29 mm. long and 21 mm. wide and was found on the shore at Navy Island, Port Antonio, having evidently been washed out of the cliff. It is smaller and has a sharper spire than the living Pacific Ocean form *R. bufonia* Gmel.

Murex (*Phyllonotus*) *pomum* Gmelin.

The anterior part and lip of the last whorl of a specimen was found at Navy Island, Port Antonio. It seems to agree more with a form of this species that occurs in the Bowden beds than with the living West Indian shell. It has two minor ridges or varices between the larger varices, whereas the living shell has only one large rough varix between each stage of growth of the last whorl. It has been about 61 mm. in length.

Oliva cf. *reticularis* Lam.

The broken anterior part of an Olive, apparently the same as the living form but also very like the most abundant Olive in the Bowden beds, was found at Navy Island. *O. reticularis trochala* Woodring, from Bowden, is now made a sub-species of the living *O. reticularis*. It has originally been about 31 mm. long.

Conus cf. *gracilissimus* Guppy.

Small and poorly preserved examples closely resembling this slender and strongly sculptured species from Bowden occur at Navy Island, Port Antonio.

Cyclostoma fimbriatulum Sow.

A cast with some of the shell remaining, evidently of this living Jamaican land operculate occurred in marly bands among the coralline limestone at Manchioneal. It is 15 mm. high and the same wide.

Orthalicus (*?*) sp.

The last whorl of a very thin-shelled form apparently a Bulimoid land shell resembling *Orthalicus* or *Strophocheilus* was found at Navy Island. When perfect it has been about 45 mm. long, with a smooth shell and straight growth lines.

Dentalium sp. Pl. XIII, Fig. 7.

A *Dentalium* about 60 mm. long and 7 mm. in diameter at the aperture occurs at Navy Island. It is slightly curved, the shell is thick and carries numerous rounded longitudinal ridges irregular in size and spacing when young but becoming more evenly spaced near the aperture, the ribs and interspaces being crossed by very fine growth lines. The aperture apparently is circular.

It does not resemble any of the Bowden forms figured by Woodring but rather recalls, but is straighter than, the recent *D. candidum* Jeffreys as figured by Dall, which ranges from the North Atlantic to Yucatan.

Barbatia (*Diluvarca*) cf. *halidonata* Dall. Pl. XII, Fig. 15.

A single right valve from Navy Island agrees with smaller specimens of this species and is 28 mm. long and 19 mm. high. Examples from Bowden were formally labelled *Arca consobrina* Sow. Woodring now makes several new species of this group from Bowden, *B. perplura*, *B. prephina*, *B. agnastha*, etc. The Manchioneal specimen resembles also *B. prephina*, but is shorter and more inflated than *B. inaequilateralis* Guppy.

Arca (*Scapharca*) cf. *nux* Sow. Pl. XII, Fig. 26.

A double valved specimen comes from Amity Hall, but may belong to the Pleistocene. It agrees with loose valves I picked up on the shore in Jamaica, and are apparently the above species. It, or a shell very like it, is reported from Panama and the west coast of Central America.

Glycymeris (*Glycymerella*) *prepennacea* Woodring. Pl. XII, Fig. 16.

1925. *Miocene Mollusks from Bowden, Jamaica*, p. 26, pl. ii, figs. 6 and 7.

A left valve and a fragment of a rather larger right-valve from Navy Island seem to agree with this species. Woodring gives a detailed diagnosis of the new sub-genus *Glycymerella* which has prosogyrate beaks and also of the species from Bowden which resembles closely the living West Indian *G. pennacea* Lam. The fossil specimens seem smaller than the living form. At the very base of the Coral Rock at the highest levels in Barbados I found a *Glycymeris* rather plentifully which comes very near but is smaller than the living *G. pennacea*, but which also resembles figures of the Bowden fossil.

Glycymeris cf. *canalis* Brown and Pilsbry. Pl. XII, Fig. 14.

A right valve from Buff Bay is 10·5 mm. high and the same broad and has about thirty-five radial ribs with angular summits and angular interspaces, and fine concentric growth lines especially in the interspaces. There are two larger growth interruptions

and the ribs tend to be slightly nodose towards the margin. It resembles small specimens of this species from the Gatun stage of Costa Rica figured by Ollson.[1] The species is related to the group of *G. acuticostata* Sow. from San Domingo.[2]

Ostrea haitensis Sowerby. Pl. XIII, Fig. 6.

Jamaican specimens have the eleven or twelve larger ridges angular, acute and deeply folded, much foliated and almost spinose. One strongly arched right valve closely resembles a figure of a specimen described by T. W. Vaughan[3] from east of La Cruz, Cuba; but no horizon seems to be given for the specimen.

Locality.—Three rather poorly preserved specimens on the under surfaces of slabby limestones at the N.W. corner of Navy Island, Port Antonio; opposite the Bath House and quite low down in the section of Manchioneal beds.

Remarks.—The original description of *O. haitensis*[4] is very brief, and there is no figure but the type specimen, rather flat and thick, is preserved in the British Museum (Natural History). It was found in the north-east part of San Domingo. It is not recorded by Woodring in his monograph on the Bowden fossils. The British Museum has some specimens collected between South Wagen and Long Bay, Anguilla by K. W. Earle in 1924 and referred to the Upper Oligocene. I have not enough examples from Jamaica to be able to say if this form is identical with *O. virleti* Desh. from the Miocene of Greece, Suez, Sinai, etc., as R. B. Newton and others have suggested.

Ostrea (*Lopha*) cf. *folioides* Woodring. Pl. XII, Fig. 5.

A left valve 57 mm. long and 36 mm. wide has sharply cut rather rounded ridges which extend from the sides nearly to the middle of the shell. A ridge down the middle marks the object, a piece of twig or coral which was clasped by the outgrowths of the opposite right valve. It is rather larger and the ribs are more numerous and more prominent than in the typical *O. folioides* from Bowden,[5] and is more elongated and narrower and has smaller and neater ribs than the living West Indian mangrove oyster, *Ostrea folium* Linn. It seems to be in some ways intermediate between the Bowden *O. folioides* and the recent *O. folium*, but rather nearer to the former in outline.

Locality.—Buff Bay, Manchioneal beds.

[1] "Miocene of N. Costa Rica," *Bull. Amer. Pal.*, vol. ix, 1922, p. 177, pl. 18, figs. 2–7.

[2] J. C. Moore, *Q.J.G.S.*, vol. vi, pp. 39–53, Pl. x, fig. 13.

[3] *Contrib. to Geol. and Pal. of West Indies*, Carnegie Inst. Pub., 1919, p. 129, Pl. 8, fig. 1.

[4] *Q.J.G.S.*, vol. vi, 1850, p. 53.

[5] W. P. Woodring, *Miocene Mollusks from Bowden, Jamaica*, Carnegie Inst. Publ., 1925, p. 61, Pl. 7, figs. 3–5.

Chama (*Pseudochama*) sp. Pl. XIII, Fig. 5.

A free left valve of a *Chama* from Navy Island is sub-circular in outline and only faintly foliated. It bears some resemblance to the corresponding valve of the recent *C. appressa* Reeve from Honduras, and of *C. ruderalis* Lam. from the West Indies.

Spondylus cf. *chiriquensis* Ollson. Pl. XIII, Figs. 1*a* and *b*.

1922. "Miocene of North Costa Rica," *Bull. Amer. Palaeont.*, vol. ix, p. 206, pl. xx, figs. 1, 2, 5, and 6.

Description.—Shell large, the beaks inflated, situated rather anterior of the median line, narrowing rapidly; a small scar of attachment occurs on the posterior side of the beak of the right valve. Hinge area is concave, the beaks rather close together, the right one higher than the left. Auricles are relatively small but thick, the posterior one the larger, decorated with growth lines, scales, and here and there spines. Both valves are about equally inflated and similarly decorated. There are six or seven unequally spaced major ribs on each valve bearing strong and coarse spines irregular in shape and size up to 21 mm. in length, sharp or scale-like. Between these are numerous smaller ribs rounded or rather angular, also irregular in size and spacing bearing small spines and scale-like protuberances. Concentric growth lines are wavy and well marked. The margins are well rounded, the lower posterior one rather produced.

Dimensions.—Height 186 mm., width 152 mm., thickness of both valves about 130 mm.

Locality.—Navy Island, Port Antonio. A perfect specimen with both valves rather displaced, collected in a clayey marl bed at the west end of the island. A broken right valve from the same bed is foliaceous about the area of attachment and bears rather long and sharp spines. Other fragments of a large *Spondylus* appear to belong to this or a very similar form and occur at Navy Island and Buff Bay.

Remarks.—This large shell comes nearest to *S. chiriquensis* Ollson from the Gatun stage, Water Cay, Costa Rica. Its general scheme of decoration also agrees with that of *S. bostrychites* Guppy from beds of Oligocene–Upper Miocene age from Anguilla, Antigua, Porto Rico; and especially with a specimen from the Miocene of Bowden, Jamaica,[1] but the present shell is much larger and the valves less circular in outline. Woodring remarks that the Bowden form may represent a different species, but in essential features it recalls *S. bostrychites*. *S. bifrons* Sow.,[2] a similar form, is from San Domingo.

Spondylus cf. *bostrychites* Guppy.

A broken valve 70 mm. across from Buff Bay may be a young of *S. chiriquensis*, but looks also very like figures of this species.

[1] Woodring, *Miocene Mollusks from Bowden*, 1925, pl. 9, figs. 5 and 6.
[2] *Q.J.G.S.*, 1850, vol. xi, p. 53.

Plicatula densata Conrad var. *jamaicensis* nov. Pl. XII, Figs. 11, 12, and 13.

Jamaican specimens comprise four attached right valves, one example with both valves (Fig. 13) and a broken left valve. The right valves are deep and variable in shape, irregularly attached by a varying portion of the surface, in one specimen by a part only of the apex, another is very strongly fixed by almost the whole surface. Plications of the right valve are coarse and irregular but not very deep, and are crossed by well marked growth lines which in one specimen become rather spinose. The upper free valve is flat or concave or rather arched, the plications more regular and rather rounded, the grooves between the folds are angular and deep. A lens shows very fine longitudinal raised punctate lines over all the surface of both valves interrupted by the growth lines. A typical right valve is 29 mm. long, 23 mm. wide, and 15 mm. deep. Sockets for the strong hinge teeth are visible in the example with both valves, but in the right valves the upper valve in breaking away has carried the apex of the shell with it and teeth and sockets are missing.

Locality.—Buff Bay, Manchioneal marls.

Remarks.—Some of my specimens resemble a figure of this species from Santiago, Cuba,[1] apparently a right valve. The Jamaican form seems to have less spinose ribs and may be a variety. The original examples of *P. densata* are from the Miocene of New Jersey.

Pecten (*Plagioctenium*) spp. Pl. XII, Figs. 9 and 10; Pl. XIII, Fig. 4.

Several separated right and left inflated valves of various sizes with rounded or flat topped ridges separated by narrow deeply scooped out interspaces and the posterior ear when present well drawn out and pointed occur in the Manchioneal beds at various places. They are comparable with *P. uselmae*, Pilsbry and Johnson; *P. concinnatus* Woodring; or *P. ameleus* Woodring of the Bowden beds. The fact of the valves of these Pectens being always separated makes identification very uncertain.

Pecten (*Nodipecten*) *nodosus* Linn. Pl. XII, Fig. 7.

Part of a right valve from Buff Bay agrees well with the corresponding portion of the recent species.

Pecten (*Amusium*) sp. Pl. XII, Fig. 8.

A damaged valve slightly convex with low rounded ribs and very faint growth lines is rather like *A. antiquensis* Brown from the Oligocene of Antigua. *Locality*, Navy Island.

Pecten cf. *barretti* Woodring. Pl. XII, Fig. 6.

Half of a flattened concave right valve of a *Pecten* of the group of the living West Indian *P. zic-zac* has prominent ribs with rounded

[1] C. W. Cooke, *Tertiary Mollusks from the Leeward Islands and Cuba*, Carnegie Inst. Publ., 1919, p. 145, pl. 11, figs. 12*a* and *b*.

summits and rounded interspaces. Fine thread-like lines of growth cross both ribs and furrows. It resembles the corresponding valve of *P. barretti* Woodring from the Bowden beds; and also *P. ventonensis* Cooke from the Oligocene of Cuba. *Locality*, Buff Bay.

Pecten (*Aequipecten*) sp.

A valve more or less circular in outline with about nineteen rounded ribs and rounded grooves resembles *A. plurinominis morantensis* Woodring of the Bowden beds. The ears are missing, but each rib carries a raised median thread line at which the lines of growth are interrupted. *Locality*, Buff Bay.

Antigona (*Ventricola*) *blandiana* Guppy. Pl. XIII, Fig. 2.

A rather crushed example with both valves joined so that the hinge is hidden agrees well with figure and description by Woodring of this species from Bowden. The type specimen is from the Dominican Republic. The lamellae are equidistant, with concentric striae between them, and the lunule is bounded by a sharp groove, the umbones are bent strongly forwards. Length 45 mm., height 39 mm.

Locality, Navy Island, Port Antonio.

Antigona cf. *rugosa* Gmelin. Pl. XIII, Fig. 3.

A single left valve from Navy Island, Port Antonio, resembles this recent West Indian form, which is also found in the Gatun stage at Port Limon, Costa Rica.

Terebratula or *Liothyrina*.

Terebratulae having a deceptive superficial resemblance to the Chalk forms *T. carnea* Sow. or varieties of *T. semiglobosa* Sow. occur at Manchioneal and were recorded there as early as 1827 by Sir H. De La Beche. R. T. Hill quotes *L. vitrea* Born. and a specimen probably of *L. bartletti* Dall from Manchioneal. Specimens of *T. vitrea*, however, that I have from the European Pliocene are much thinner shelled than the Jamaican forms. *Liothyrina* (*Terebratula*) *carneoides* Guppy was described from gypseous marls (of the lower Miocene ?) with *Orbitoides mantelli* and *Nummulina* near San Fernando, Trinidad. The British Museum also has a series of specimens of *T. carneoides* from beds called lower Miocene in the island of St. Bartholomew. C. W. Cooke records *Liothyrina vaughani*, a species formerly recorded by Cleve as *T. carneoides* from upper Eocene of St. Jean Bay, St. Bartholomew.[1]

My five or six *Terebratulae* from Manchioneal do not seem to resemble *T. carneoides* nor *L. Vaughani*, and all of them have the beak and foramen of the dorsal valve closely incurved against the beak of the ventral valve, a well-truncated foramen, and a shell thick and solid towards the foraminal region, well marked and regular growth lines and the test faintly and minutely punctate.

[1] *Tertiary Mollusks from Leeward Islands and Cuba*, Carnegie Inst. Publ., 1919, p. 152, pl. 16, figs. 1*a–c*.

They appear to come nearer the living forms *T. cubensis* and *T. bartletti*, but I cannot find any recent specimens of these species in this country to make a direct comparison.

Terebratula cf. *cubensis* Pourtalès. Pl. XII, Fig. 1.

A specimen with a fairly solid shell, length 31 mm., width 24 mm., and thickness 22 mm., resembles figures of this species. It seems to have very little anterior plication. Its present range is described [1] as from Florida reefs to Barbados and range in depth as $\frac{80}{400}$ fathoms. Manchioneal.

Terebratula cf. *bartletti* Dall.

A dorsal valve 40 mm. and 29 mm. wide showing the foramen and bases of the crura has the general appearance, and considerable degree of anterior plication of this species.[2] The shell is quite thick in the foraminal region. Manchioneal.

Terebratula sp. Pl. XII, Fig. 2.

A specimen narrowing towards the foramen and widening anteriorly, but with only a slight anterior plication may be a variety of *T. cubensis*. It is 31 mm. long, 24 mm. wide, and 19 mm. thick. Manchioneal.

Terebratella (*?*) sp. Pl. XII, Fig. 3.

Shell wider than high, both valves about equally convex, the ventral with a faint broad median sulcus, the dorsal evenly convex. The hinge and foraminal region are broken away. Both valves have about twenty-six rather wavy rounded ribs, some passing completely from beak to margin, others intercalated about halfway or at varying distances from the margin. The surface appears coarsely punctate under a lens. Width 12 mm., height about 10 mm., thickness about 6 mm.

Locality.—Navy Island, Port Antonio.

Terebratulina caput-serpentis Linn. Pl. XII, Fig. 4.

A Brachiopod 12 mm. long, 10 mm. wide, and 6 mm. thick across the valves seems to agree in every outward respect with this species. I have compared it with figures and also with six or seven recent specimens from Norway. The foramen is obliquely truncate and the shape and ribbing similar. The dorsal valve shows a shallow median anterior furrow and the ventral a corresponding fold, but recent specimens vary in degree of folding. The shape varies between that on Davidson's pl. i, figs. 3 and 15*a*.[3] S. P. Woodward gives the range of *T. caput-serpentis* as from Norway to the Mediterranean, and the depth of sea from 10–120 fathoms. Off West of Ireland Davidson gives the range as 90–808 fathoms; it is also recorded from Sagami Bay, Japan; North America; Spitzbergen; Naples, etc. From Manchioneal beds at Innes Bay.

[1] W. H. Dall, *Bull. U.S. Nat. Museum*, Smithsonian Inst., 1889, No. 37, p. 28, pl. xxxix, figs. 6 and 10.

[2] Ditto, p. 28, pl. vi, figs. 4 and 4*c*.

[3] *Brit. Fossil Brachipoda*, Palaeontogr. Soc., 1851–5 vol. i.

Cuneolina cf. *pavonia* d'Orb. Pl. XII, Fig. 25.

A specimen 5·75 mm. high, 6 mm. wide, and about 2·5 mm. thick was collected together with *Ostrea haitensis* in the lower beds at the south-west corner of Navy Island, Port Antonio, opposite the bath house. It is poorly preserved, but is very like a specimen of this triangular shaped arenaceous foraminiferon figured by J. A. Cushman.[1] He says it is one of the commonest and most striking of the Bowden species.

Cristellaria cf. *calcar* Linn.

The clay matrix of the Manchioneal beds at Port Antonio and elsewhere is charged with foraminifera among which forms of *Cristellaria* are conspicuous.

CORALS.

Dr. T. Wayland Vaughan has kindly sent me the following notes after his examination of the Corals I collected in the Manchioneal Beds.

From Manchioneal.

Orbicella limbata var. *tegula* (Duncan). Upper or Middle Miocene.

Maeandra sp. cf. *M. strigosa* (Dana). Quaternary or older, may be Miocene.

From Buff Bay.

Dichocoenia tuberosa (Duncan).

Orbicella cavernosa (Linn.).

Thysanus.

Agaricia agaricites (Linn.), two varieties. Miocene.

From Navy Island, Port Antonio.

Probably *Madracis*, two species, both apparently new.

Pavona ? sp. Probably Miocene.

Pocillopora sp. cf. *P. crassoramosa* (Duncan). Miocene.

Solenastrea bournoni (M. Edw. & H.). The calices are decidedly small, about 1·5 mm. is a common diameter. Probably Miocene.

Stylophora sp. ; perhaps *S. granulata* (Duncan). Miocene.

He remarks that although there may be one or two Quaternary specimens mixed with the others, the material in general is definitely Miocene and represents the Bowden horizon, which is correlated with the Gurabo Formation in the Dominican Republic.

ECHINODERMS.

Professor H. L. Hawkins, of Reading, has favoured me with the following notes on a few Echinoderms and echinoderm spines I collected in the Manchioneal beds.

1. *Cidaris* Spines from Navy Island.

It is unsafe to rely on such material, since many different genera of Cidarids have closely similar spines. I should say that these may

[1] *Fossil Foraminifera from the West Indies*, Carnegie Inst. Publ., 1919, p. 34, pl. vii, fig. 1.

well have belonged to some such recent forms as *Stylocidaris affinis* Philippi, which lives now in the district at depths from 30–100 fathoms. In earlier days they would probably have been dismissed as "*Goniocidaris*", but that genus does not live in the Antillean district now.

2. Manchioneal Harbour. *Echinoneus cyclostomus*, Leske.

The large oval test is one of the innumerable shape-variants of *Echinoneus cyclostomus*, Leske, a common recent West Indian species. It seems to range almost unchanged in essentials, though protean in shape, throughout the Tertiary, at first in the Mediterranean region, but now essentially Antillean.

3. Manchioneal Harbour. *Echinolampas* (?) sp. nov. (?).

This is a puzzle. Until it was cleared of matrix I took it for a round variety of the former, but it is not. The nearest I can find to match it is a figure of a young recent *Echinolampas depressa* Gray in Agassiz's *Revision of the Echini*. Its peristome is too deep, but otherwise the correspondence seems fairly exact. I don't think that *E. depressa* lives anywhere near Jamaica, nor does any *Echinolampas*, so far as I know, though there are many Eocene and Oligocene relatives there.

The general inference points towards very late Pliocene or Pleistocene; but No. 2 might be anything Tertiary and No. 3 is rather dubious.

Correlation.

The Mollusca and also the Corals of the Manchioneal beds show a decidedly closer affinity with those of the Bowden beds than with the living fauna, a feature I hardly expected to find in view of the position of the beds immediately under the Coral rock or Coast limestone. The number of species in the Bowden fauna closely allied to, if not actually identical with, the living forms is remarkable. Furthermore, the Bowden and Manchioneal formations both enter equally slightly into the tectonics of Jamaica. They never occur so far as I know in any of the inland or upland valleys, but are purely marginal in distribution. Hitherto the Manchioneal beds have been referred by most writers to the Pliocene, presumably on account of their position rather than their fauna, which has been practically uninvestigated. Possibly if they were in Europe the Manchioneal and perhaps also the Bowden beds might be placed in the Pliocene rather than the Miocene.

Perhaps it will be better for the present provisionally and with some doubt to refer them to the Pliocene, but at what horizon is not easy to say, owing to the scantiness of the fauna, but presumably a low horizon. One may well ask why is there no prolific Pliocene fauna in Jamaica; can it have been a land surface, a supposition which might account for the very rotted and dissolved condition of the Manchioneal beds and of a great part of the White Limestone?

C. T. T. Photo.

MANCHIONEAL FOSSILS FROM JAMAICA.

To face p. 217.]

W. P. Woodring refers to the poverty of the West Indian Pliocene faunas when compared with those of the Piedmont basin, for instance, and contrasts the relative richness of the West Indian and Central American Miocene. Referring to the neighbouring island of Haiti, Woodring writes[1]: "One of the surprising results of the reconnaissance is the discovery that the tectonic features of so large a part of the Republic are due to folding and crumpling of the rocks at the end of Miocene time. The Central Plain, Artibonite Valley, and Cul-de-Sac Plain are deep synclinal troughs of the same age. Miocene beds are involved in the folding in the North-west Peninsula. Many of these mountain ranges and troughs are bordered by high-angle thrust faults." In Jamaica, assuming the Bowden beds to be Miocene the crumpling movements seem to have come to an end earlier than in Haiti. The Bowden beds, which Woodring[2] now refers to the higher part of the Middle Miocene, or the Tortonian of Europe, as already stated have only suffered or been subjected to a moderate degree of elevation since the commencement of their deposition.

Whether Jamaica is separated from the adjacent islands by down-faulted troughs, or by high-angle thrust faults such as Woodring describes in Haiti remains to be determined. Its long isolation, however, is indicated by its land mollusca, scarcely one of its fifty-six genera or over 440 species of which occurs elsewhere. The genus *Strophia*, or beehive shells, is quite absent from Jamaica, though various species of the genus occur in myriads in the Bahamas, Cuba, the Cayman Islands, Curaçao, Porto Rico, Key West, Florida, etc.

EXPLANATION OF PLATES XII AND XIII.

All specimens are represented natural size unless otherwise stated, and all are from the Manchioneal beds except perhaps Pl. XII, Fig. 26.

Plate XII.

FIG.

1. *Terebratula* (*Liothyrina*) cf. *cubensis*. Pourtalès. Manchioneal.
2. *Terebratula* (*Liothyrina*) cf. *cubensis* var. Manchioneal.
3. *Terebratella* (?) sp. Navy Island, Port Antonio.
4. *Terebratulina caput-serpentis*. Linn. Innes Bay, ventral, and side view.
5. *Ostrea* (*Lopha*) cf. *folioides*. Woodring. Buff Bay.
6. *Pecten* cf. *barretti* Woodring, right concave valve. Buff Bay.
7. *Pecten* (*Nodipecten*) *nodosus* Linn., part of a right valve. Buff Bay.
8. *Pecten* (*Amusium*) sp. A damaged valve. Navy Island, Port Antonio.
9. *Pecten* (*Plagioctenium*) sp., a left valve. Manchioneal.
10. Ditto, another left valve damaged. Manchioneal.
11. *Plicatula densata conrad*, var. *Jamaicensis* nov.; interior of a right or attached valve. Navy Island, Port Antonio.
12. Ditto, exterior of a right or attached valve. Same locality.

13*a* and *b*. Ditto, a specimen with both valves, (*a*) right or attached valve, (*b*) view of the free or left valve. Navy Island, Port Antonio.

[1] *Journ. Washington Acad. of Sciences*, vol. xiii, No. 7, April, 1923, p. 124.
[2] *Miocene Mollusks from Bowden, Jamaica*, part ii, Carnegie Inst. Publ., Nov., 1928, p. 39.

FIG.
14. *Glycymeris* cf. *canalis* Brown and Pilsbry; a right valve internal and external view. Buff Bay.
15. *Barbatia* (*Diluvarca*) cf. *halidonata*, a right valve. Navy Island, Port Antonio.
16. *Glycymeris* (*Glycymerella*) *prepennacea* Woodring. Navy Island, Port Antonio.
17. *Cypraea* cf. *cinerea* Gmel. or Linn. Navy Island, Port Antonio.
18. *Ranella* (*Lampadopsis*) cf. *thomae* d'Orb. Navy Island.
19. *Turritella exoleta* Linn. var. *Jamaicensis* nov. Buff Bay.
20. Ditto; another example. Navy Island, Port Antonio.
21. *Ianthina* cf. *communis* Lam. Manchioneal.
22. *Drillia* sp.; a broken specimen. Manchioneal.
23. *Natica* (*Stigmaulax*) *vererugosum* Cossmann. Navy Island, Port Antonio.
24. *Recluzia* cf. *hargravesi* Cox. Navy Island, Port Antonio. A sketch.
25. *Cuneolina* cf. *pavonia* d'Orb. Navy Island, Port Antonio.
26. *Arca* (*Scapharca*) cf. *nux*. Sow. Amity Hall; Pleistocene (?).

PLATE XIII.

1*a* and *b*. *Spondylus* cf. *chiriquensis* Ollson; (*a*) view of left valve, (*b*) view of both valves conjoined. Rather over ⅓ nat. size. Navy Island, Port Antonio.
2. *Antigona* (*Ventricola*) *blandiana* Guppy. View of right valve. Navy Island, Port Antonio.
3. *Antigona* cf. *rugosa* Gmelin. Left valve. Navy Island, Port Antonio.
4. *Pecten* (*Plagioctenium*) sp. Navy Island, Port Antonio.
5. *Chama* (*Pseudochama*) sp.; a left valve. Navy Island, Port Antonio.
6. *Ostrea haitensis* Sow. Navy Island, Port Antonio, lower beds.
7. *Dentalium* sp. A fragment. Navy Island, Port Antonio.
8. A Coral (?) *Pectinia* sp. Buff Bay.

The Heavy Mineral Suites and Correlation of the Granites of Northern Brittany, the Channel Islands, and the Cotentin.

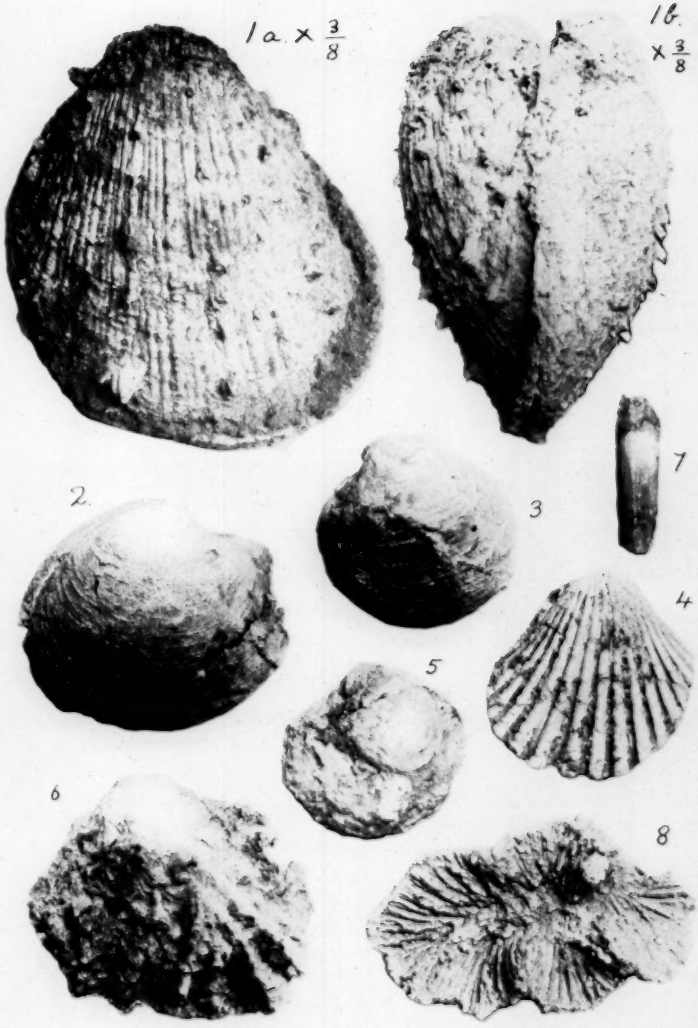
By A. W. GROVES, PH.D., M.SC., D.I.C.

(PLATES XIV AND XV AND FOLDING TABLE.)

I. INTRODUCTION.
II. GROUP I GRANITES.
III. GROUP II GRANITES.
IV. GROUP III GRANITES, AND LA HAGUE MASSIF.
V. GROUP IV GRANITES.
VI. GROUP V GRANITES.
VII. GROUP VI GRANITES.
VIII. GROUP VII GRANITES.
IX. ST. MALO GNEISSES, SOUTHERN BRITTANY, CHAUSEY ISLANDS, LES MINQUIERS, LES ECRÈHOUS, PATERNOSTERS, AND HERM.
XI. DISCUSSION AND SUMMARY.
XII. CORRELATION OF GRANITE MASSES BY THEIR HEAVY MINERAL SUITES.

I. INTRODUCTION.

THE area studied includes the majority of the main granite masses north of the belt of Ordovician and Silurian rocks running eastwards from Quimper to around Vitré and Laval. The heavy minerals of the Channel Islands granites have already been described by the writer (1). In the present paper the work is extended to the northern half of Finistère, and the greater part



C. T. T. Photo.

MANCHIONEAL FOSSILS FROM JAMAICA.

[To face p. 218.

of the Côtes-du-Nord, Ille-et-Vilaine, and Manche. It is confined for the most part to the granites, and comparisons are made with those of the Channel Islands in an endeavour to obtain more definite evidence as to the age of the Jersey " Newer " Granites.

While, for obvious reasons, the scale of the investigation cannot be compared with that of the recent work on the granites of Devon and Cornwall by Dr. Brammall, Dr. P. K. Ghosh, Mr. J. G. C. Leech, and Mr. M. Chatterjee, it is hoped that sufficient detail is here given to assist sedimentary petrographers on questions of provenance—especially those arising in Southern England—until such time as the mineral suites of these granites are each more fully investigated. Stress minerals from the area immediately to the south of that here dealt with, and from probable former extensions, are known to occur at a number of horizons in the stratigraphical sequence of the South of England. As soon as the granites of Northern Brittany and Normandy were unroofed, it is clear on general grounds that they must also have contributed extensively to these sediments. Considerable amounts of detritus from these granites have been detected by the writer in certain of the Cretaceous and Eocene rocks of Southern England, and it is hoped that an account of these occurrences will be published in the near future.

The granites are shown on the French official geological map[1] as granite and " granulite ",[2] symbols being frequently given to indicate the approximate ages of the masses. They are variously assigned to the Pre-Cambrian, Devonian, and Permo-Carboniferous, but in a number of cases no indications as to age are given. When the distribution of the various granites is studied in relation to the tectonics the masses are seen to be elongated and aligned along definite axes trending from N.E.–S.W. in those areas skirting the English Channel, to E.-W. in Central Brittany. This elongation of the granite masses along fold lines is even more strikingly demonstrated in the belt of country from Quimper to Nantes, where also the trend has swung round to N.W.–S.E. These axes of alignment have been demonstrated by Professor Ch. Barrois, from one of whose papers (2) Fig. 1 is taken. It has been considered conducive to correlation of the granites—as far as the laboratory examination is concerned—to examine those lying along the same fold axes, or general trend, collectively before proceeding to the examination of the next belt of intrusions. It is therefore proposed to deal with the granites according to the following grouping :—

Group I.—The belt of granites fringing the N.W. coast of Finistère from N.W. of Ploudalmézeau, eastwards through Brignogan, Plouescat, to Roscoff, continuing seawards in the Île de Batz, Île Grande, and Les Sept Îles.

[1] The map referred to in each case is the " Carte Géologique de la France ", issued by the Ministère des Travaux Publics, 1 : 1,000,000, 1905 Edn.

[2] This term is generally used for the granites in which muscovite is the dominant mica, but has not been very rigidly adhered to.

Group II.—The " Granite Porphyroïde de l'Aber-Ildut " of the French Geological Survey, marked as γ_{II} (Cambrian to Devonian), forms a well-defined belt of granites running from an island on the Plateau de la Helle, S.W. of Ouessant, around l'Aber-Ildut, on the coast opposite Ouessant, eastwards through St. Pol de Léon, Carantec, N.W. of Plougasnou, out to sea in the Chaises de Primel, and occurring again in the Côtes-du-Nord at Pleumeur, Trégastel, and Ploumanac'h. It has been suggested by Barrois (3) that the granites of Jersey and Flamanville also lie on this belt, while Lecornu (4) suggests a connection between the Jersey, Flamanville, and Barfleur masses. The axis of the Group II granites shows a Caledonian trend and is practically parallel with that of the granites of Devon and Cornwall.

Group III.—The " Granite de Perros " from just north of Lanmeur to Perros Guirec, Sillon de Talbert, and Île Bréhat.

For convenience, and because their mineral suites bear no resemblance to those of Groups I, II, IV, VI, etc., but are not unlike those of the Perros Granite, the rocks of the Cap la Hague district are considered here.

Group IV.—A large elongated granite mass running E.N.E. from Brest towards Morlaix has more or less in line with it the enormous mass extending around Plouaret and Bégard, and comparable in size with the Dartmoor granite. The granite of St. Michel-en-Grève is also included here. Lying more or less in between this group and the next is the Guingamp granite.

Group V.—A crescent-shaped axis of alignment of foliated rocks centring round St. Brieuc.

Group VI.—A nearly E.–W. belt formed by the Huelgoat, Quintin, Moncontour, Dinan, St. Marcan, Avranches, and la Ferté-Macé granites.

Group VII.—A group of granites running from Rostrenen eastwards to the Fougères granite.

II. Group I Granites.

This group[1] is composed of biotite and biotite-muscovite granites of a leucocratic and rather acid type. Biotite is always in excess of muscovite, and even in the " granulites " there is three or four times as much biotite as muscovite. The index figure is about 5 for the " granulites ", but rises to 11 in the porphyritic granite east of Cléder. Apart from micas, zircon, apatite, and sphene are the only constant heavy minerals, though there are sporadic occurences of andalusite, tourmaline, rutile, and rare monazite.

The zircons occur in two types, one a pale buff-coloured poorly zoned type and the other water clear. Of the two types the second is very much in a minority. In both types the steep pyramid (311)

[1] For list of localities from which specimens have been examined, see table of occurrences, facing p. 232.

is dominant, and many of the habits of the Cornish granite zircons are to be observed. The apatite grains often contain a pleochroic core, but this feature is not so common, nor are the crystals so well formed, as in the Group II granites. The types of cores in the apatite of the granites of Groups I and II are the same. Sphene is not so plentiful as in Group II. The differences between this suite and that of Group II are mainly quantitative rather than varietal, the general characters of the two groups being remarkably similar.

The tourmaline observed in the "granulite" 3 km. south of Brignogan was all deep green. Much andalusite with a strong

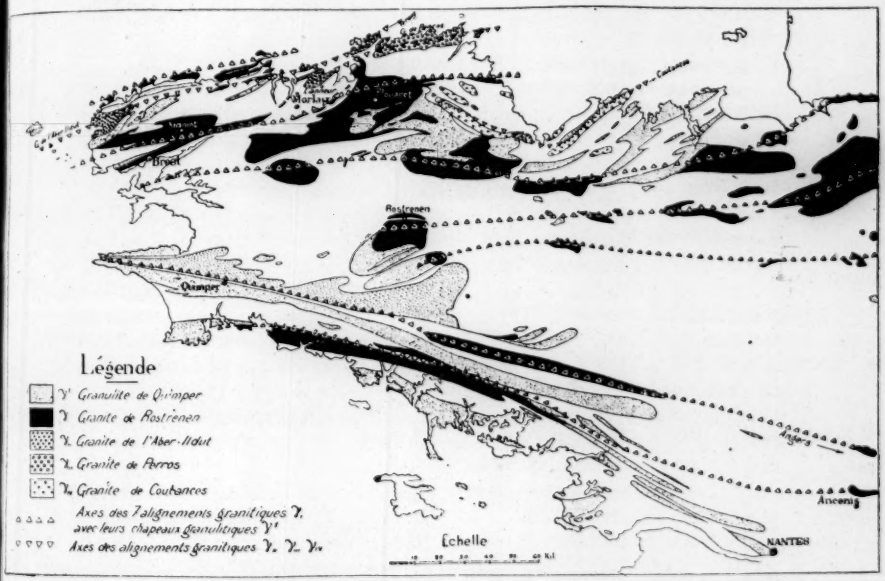


FIG. 1.—Axes of alignment of the granites of Brittany, from *Le Calcaire de la Vallée du Dourdu*, by Ch. Barrois (2), reproduced by kind permission of Professor Barrois and La Société Géologique du Nord.

rose flush occurred in the specimen of porphyritic granite of Brignogan beach, and well developed brown prismatic crystals of rutile in the porphyritic granite east of Cléder.

III. GROUP II GRANITES.

These granites are remarkably constant in their appearance in the field over the whole distance from Trégastel to l'Aber-Ildut, N.W. of Brest. They are coarse-grained biotite granites with large porphyritic crystals of pink orthoclase from 1 to 3 inches long. They are more basic and melanocratic than those of Group I, and were probably injected rather earlier. At Trégastel and Île Melon the granite is often crowded with dark xenoliths elongated

parallel to the general " flow " direction of the porphyritic felspars, and it would seem that the granite exposed in these places is near the roof. The Brittany granites generally form no outstanding physiographic features, having all been planed down to approximately the general level of the country. In consequence tors such as characterize Dartmoor are very rare ; at the same time weathered out boulders up to 20 feet and fantastically shaped rocks up to 50 feet dominate the scenery around Trégastel and Ploumanac'h. In many places, particularly around Trégastel and Pleumeur, there is a striking resemblance to the red variety of Shap Granite.

Some of the pink porphyritic granites of Jersey are similar to varieties of the Group II belt of granites in Brittany. The Flamanville granite of Normandy also shows a striking field resemblance to the other granites on this belt, both in Jersey and Brittany. All the foregoing have been reddened, probably by autopneumatolysis at a late stage in the consolidation. The Barfleur granite, while similarly porphyritic, is not always reddened and is in part grey resembling the Cornish granites and the grey porphyritic granites near Brignogan, Cléder, Ploeuc, Bégard, and elsewhere in Brittany. The Jersey and Flamanville granites form physiographic features, but the Barfleur area is very flat.

From l'Aber-Ildut to Trégastel the heavy mineral suite is remarkably constant. The index figure varies from 7–17, the great bulk of the heavy residue being always biotite. An average figure is about 7–8, higher figures being due to assimilation accompanied by increased production of biotite. Iron ores are extremely scarce, though pyrite sometimes occurs. The important minerals for correlative purposes are zircon, apatite, and sphene, the first two displaying very definite varietal characters. Most specimens yield only these three heavy minerals together with biotite. Occasionally rare monazite is present. No tourmaline and only one grain of rutile have been observed, except in the Normandy granites. Rutile, anatase, and brookite together with topaz, andalusite, and tourmaline are essentially absent and this is in striking contrast with the granites of Devon and Cornwall. It is probably due to the poor development of local pneumatolysis—as distinct from large scale autopneumatolysis of the type which merely causes reddening of the felspars. As a rule muscovite is not developed to any appreciable extent.

The zircons occur in two types, a zoned and a clear type, in habits reminiscent of many of those to be found in the granites of Devon and Cornwall. This remark also applies to the Flamanville and Barfleur granites and to the Jersey " Newer " granites. In no case, however, does the zoning reach the perfection displayed by the Dartmoor zoned zircons. The dominant habit of the zoned zircons of the majority of samples examined from Normandy and Brittany is the very simple combination of prism and unit pyramid, with the length only $2\frac{1}{2}$–4 times the width. The steeper pyramid (311) is generally absent or only slightly developed. Locally, however,

crystals are more elongated and the (311) becomes dominant, the crystal assuming the " torpedo " habit described by Leech from the St. Austell mass. The proportion of zoned to clear zircons varies from about 20 : 1 to 100 : 1, but is generally about 50 : 1. The clear zircons, from the Atlantic coast to Barfleur occasionally contain zoned zircons as inclusions indicating that the clear type are later than the zoned ones.

The writer has during the last three years made a close study of the mineral assemblages of the granites of Devon and Cornwall, and although the belt of granites under discussion differs in many respects from the parallel belt in South-West England, yet the general similarity of the zircons in the two cases appears too remarkable

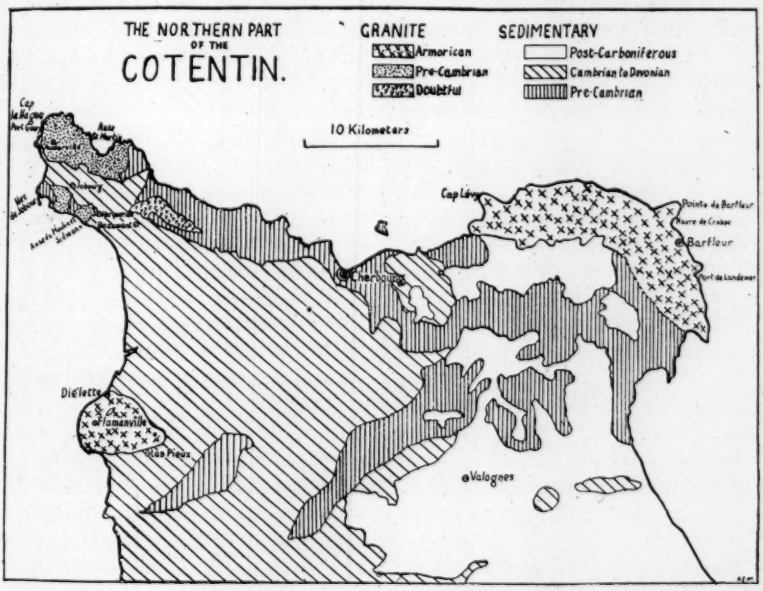


FIG. 2.—The Northern part of the Cotentin Peninsula, adapted from the Carte Géologique de la France.

to be put on one side as a mere coincidence. Speaking generally, the zircons of the Armorican granites of Devon and Cornwall show a marked tendency for the degree of zoning to become more perfect, and the individual zones to become more closely packed, in an easterly direction, reaching a maximum in the Dartmoor granite. In the Group II granites a similar broad generalization may be made, the zoning becoming more intense in the Trégastel, Flamanville, and Barfleur masses. (See Plate XIV.)

The apatites throughout the belt, including Jersey and Normandy, contain central cores of inclusions of several characteristic types which have been described by the writer elsewhere (5). Definite cores of inclusions have not been observed in the apatites of the

granites of the south-west of England, although there is some approach to them in the St. Austell mass. There is never any shortage of the mineral which is always present in well formed, often rather stout, crystals.

The sphene is always brown to yellowish-brown and sometimes in large well-crystallized grains; owing to the cleavage, however, they have a marked tendency to break up in the crushing. Sphene is particularly abundant at Trégastel and Diélette.

Leclère (6) demonstrated in a chemical study that there were significant variations in the composition of the Flamanville granite, the marginal parts being apparently contaminated by absorption of sedimentary rocks.

A comparison of material from near Artot aux Fourneaux in the centre of the mass with specimens from the large quarry at Diélette on the margin supports this conclusion. The Artot specimen was weathered, but this cannot entirely account for the fact that the index figure was only one quarter of that at Diélette.

Zircon and apatite of the normal Group II types were present in both cases. On the other hand hornblende and biotite were much more abundant at the margin than at the centre while sphene, of which the Artot specimen contained only two or three grains, was extremely abundant in Diélette. At Artot muscovite, tourmaline, anatase (brown, tabular and bipyramidal), brookite (pale yellow), and monazite (one grain, elongated) also occurred. The difference thus appears to be due to marginal absorption of titaniferous sediments together with a little pneumatolysis at the centre. Leclère unfortunately did not determine titanium in the granites and neighbouring sediments which he analysed.

The Barfleur granite tends to lie somewhat north of the trend line of the Group II granites, but its heavy minerals clearly indicate its close genetic connection with them. It has the two types of zircon, a zoned, and a clear type together with apatite with central cores of inclusions. Its mineral suite combines most of the characters of the granites of Groups I and II. It is particularly closely related to the Artot type of the Flamanville granite as shown by the occurrence at its eastern end of abundant muscovite, common monazite (tabular), with anatase (tabular, brown), rutile and some rare tourmaline. These minerals and the appearance in hand-specimen at this end of the mass demonstrate a tendency towards affinity with the Dartmoor granite. The hornblende, as at Jersey and Flamanville, is probably due to assimilation.

The age of the Group II belt of granites is in a number of instances given on the French official maps as Cambrian to Devonian. Barrois shows that it is Post-Dinantian and assigns it to the Namurian (3). In Brittany the granites are intrusive into various gneisses and schists probably of Pre-Cambrian age; in Jersey into presumed Pre-Cambrian shale, while the Barfleur granite is intruded into the Phyllades de St. Lô. The contact of the Flamanville granite on the coast has been described by Prof. A. Bigot and Michel-Lévy (6). Some

distance north of the Flamanville granite metamorphosed Lower Devonian rocks rest upon Silurian beds. The most characteristic Devonian beds are the schistes de Néhou which contain lenticular beds of limestone and discontinuous coral reefs. Above and below are shales. A fault separates these from the metamorphosed beds which are actually invaded by the granite. All the beds can be identified, and in particular the structure of the Schistes de Néhou is recognizable with the limestone converted into a rock consisting largely of garnet. The intervening shale beds also contain a few pyritized fossils. A small Cretaceous outlier rests upon the granite. The above evidence, while not as straightforward as might be desired leaves little doubt that this granite is later than the Lower Devonian and therefore almost certainly Permo-Carboniferous.

Comparison of the mineral assemblages of the granites of Groups I and II clearly shows that these granites have a very close genetic relationship and must have been derived from the same magma reservoir. They are therefore probably more or less contemporaneous.

IV. Group III Granites.

The specimens examined of the "Granite de Perros-Guirec" from Perros-Guirec, Kermaria-Sulhard, Sillon de Talbert, and Île Bréhat were very different from those of Groups I, II, IV, VI, and VII. The index figure varies from 4–10, and the appearance in the hand-specimen is quite different from that of the other groups of granites. All the crystals of zircon and apatite are much smaller than those of the other groups. The zircons are all clear and of simple type. Apatite is not very plentiful and no real cores of inclusions are developed.

The mineralogical evidence of the heavy minerals of this group of granites gives no indication of genetic relationship with the granites of Groups I, II, IV, VI, and VII. This is in agreement with Prof. Barrois who considers the "Granite de Perros" to be older than the "Granite Porphyroïde de l'Aber Ildut" (Group II granites) and also states that pebbles of Perros granite occur in the Poudingue du Dourdu (Carboniferous) (2).

La Hague Massif.—Three specimens of the granite around Anse St. Martin yielded very similar mineral suites to those described by the writer from the "Older" granites of the Channel Islands. A specimen from E. of Anse St. Martin was full of shale xenoliths and the index figure is accordingly very high. The zircons in this last rock are very variable and some are probably derived from the assimilated material, i.e. are xenocrysts. A specimen from the W. end of Anse St. Martin with index figure 6·3 is of a porphyritic granite occurring in immense blocks surrounded by ordinary granite. Mr. A. E. Mourant states that similar blocks occur in the Jobourg granite. The heavy mineral suite of this porphyritic granite is similar to that of the containing granite and it would appear that

the included blocks of porphyritic granite are masses of an earlier cooled portion of the magma disrupted and carried up from a lower level.

The La Hague mass has been classed with the Flamanville and Barfleur granites, but examination of the mineral suites clearly shows that it bears no genetic relationship to them, and has many points in common with the " Older " granite of the Channel Islands and the Perros granite of Brittany. It is also significant that in both the La Hague and Jobourg masses there are disrupted blocks of an earlier porphyritic granite. Thus the La Hague mass is probably Pre-Cambrian as suggested by Prof. A. Bigot and Mme. E. Jérémine (20).

Jobourg and Herqueville Masses.—These two small masses lie a few kilometres south of the La Hague mass and just south-east of the Nez de Jobourg. Four of the specimens examined from these complexes are distinctly foliated and fall into the category of orthogneisses. In the handspecimen they are not unlike the gneisses of Southern Guernsey and are probably of the same age. A specimen from Anse du Moulinet is of a fine grained granite yielding a suite of minerals reminiscent of those of the " Older " granites of the Channel Islands. This is a later intrusion than the gneissic rocks.

A specimen of the dioritic gneiss from the west of Anse de Moulinet, about 2 km. E. of Jobourg, is strongly foliated and has an index figure of 30. Its monazite content, which is considerable, is of especial interest. Over 95 per cent of the monazite grains are beautifully rounded or ovoid, while the remainder are euhedral. The tint of yellow displayed by this mineral is sometimes brownish, while the average size of the grains is ·1–·2 mm., the largest grain being ·25 mm. Among the euhedral grains the following forms have been recognized[1]:—a(100), m(110), r(111), v($\bar{1}$11), w($\bar{1}$01). Euhedral crystals are commonly flattened parallel to a(100) giving a tabular habit. At the same time there are some having an almost prismatic habit due to the elongation of v(111). The fact that in this case the majority of the monazite grains are rounded shows that the presence of rounded grains of this mineral in a sediment does not necessarily entail wear and tear. A similar case has been noted in connection with ovoid zircons (1, p. 472) (8). The rounding of the monazite does not appear to be connected with earth movements, as in the case of the zircons referred to, for perfectly euhedral monazites also occur, and grains have been noted in intermediate stages of corrosion. Dr. Brammall has also noted both rounded and euhedral monazites in the Dartmoor granite (7). Both in Dartmoor and the present case there is a tendency for the rounded grains to be darker in tint than the euhedral ones. Either monazite has a tendency to crystallize out in the form of droplets devoid of crystal faces or else it is liable under suitable conditions to corrosion after crystallization. (See Plate XV).

[1] The notation used is that of Dana's *System of Mineralogy*.

Two other specimens of gneisses from the shore opposite the islet of Sidman yielded similar mineral suites with monazite. A feature of both the granitic and dioritic gneisses is the presence of yellow zircons showing a basal parting.

V. Group IV Granites.

Specimens collected from the eastern end of the Bégard mass around the town of Bégard show that this part of the mass, at least, has a very variable index figure and locally is more basic than any of the other non-foliated masses examined. The index figure rises to 23 in the dark variety (dioritic) quarried 600 metres N.W. of Bégard where pale green hornblende is abundant in addition to biotite. In the more normal granite the index figure is 10–13.

The heavy mineral suite, apart from biotite and hornblende already mentioned, consists of sphene, apatite, zircon and occasional pyrite. The zircons are comparatively large and occur in two types : a buff zoned type of simple habit with unit pyramid as the dominant pyramid and a clear type, there being some fifty zoned zircons to every clear one. The apatite crystals are very well developed and central cores of inclusions of several types are moderately common. The sphene is yellowish-brown, while some rare monazite is also present. These characters can leave no doubt that this mass is comagmatic with the granites of Groups I and II already described.

A specimen from S.W. of Ploulech of the tongue of granite running seawards towards St. Michel-en-Grève is of a grey granite slightly reddened and altered by local pneumatolysis and contains some muscovite in addition to biotite. As a result of the pneumatolysis this specimen differs from nearly all the others examined in containing fairly common steel-blue tabular anatase and rare almost colourless, weakly striated, brookite. Rutile and tourmaline were not observed, however. The zircons are of two types : a buff-coloured partially zoned, and a clear type. The habits are variable, but all are of types which the writer finds to be generally associated with Armorican granites, many Cornish types being present. The apatites are well crystallized and contain numerous well developed cores of inclusions of different types. Scarce monazite of octagonal and prismatic habits occurs with brown inclusions similar to the inclusions in the monazite of the Devon and Cornish granites. Apart from the effects due to pneumatolysis, this granite is clearly comagmatic with the Bégard granite and related to the granites of Groups I and II.

A specimen of the Brest granite from N.W. of St. Renan yielded the zoned and clear type of zircon, apatite with cores, scarce monazite also tourmaline and andalusite in addition to biotite and muscovite. These characters show that it is closely related genetically with Group IV.

Guingamp Mass.—Both muscovite and biotite granites occur in the Guingamp mass which forms an extensive area of granite and

" granulite " lying more or less in between the axes of alignment of Groups IV and VI. The unfoliated specimens yield a mineral suite similar to that of the other granites of Groups IV and VI while the foliated specimens are very similar to the foliated material from the neighbouring Quintin granite. In the specimen of " granulite " 2 km. W. of Guingamp the white mica is of an unusual kind, most of it being decidedly lighter than bromoform.

VI. Group V Granites.

This arcuate belt of rocks centring upon St. Brieuc is correlated by the French Geological Survey with the Coutances mass, all the rocks on this belt being designated " Syénite de Coutances ". They are strongly foliated and their Pre-Cambrian age is indicated by the Cambrian sediments resting unconformably upon them at Erquy and Anse de Sevigné. The specimens examined range from granitic gneiss to basic dioritic gneiss, the index figure ranging from 10 to 46. The specimen from Plevenon in particular, closely resembles the L'Erée dioritic gneiss of Guernsey in its macroscopic characters. The dominant heavy mineral is hornblende and in the specimen from Moulin de Quélard, east of Erquy, the amphibole is a very pale variety. Zircon is rare or absent and apatite is not always present, but when it does occur the crystals are devoid of faces. No cores of inclusions were observed in the apatites.

As might be expected, the heavy minerals of this group have nothing in common with those of Groups I, II, IV, VI, and VII.

VII. Group VI Granites.

The Quintin granite consists of both biotite and biotite-muscovite granites and is in part foliated. The heavy mineral suite of the foliated specimens differs little from that of the unfoliated material. The only differences are to be observed in the apatites which, in the foliated granite, tend to crystallize less perfectly and without well developed cores of inclusions. The usual two types of zircon are present and the character of the mineral suite is in accordance with the other granites of this group.

Specimens from near Ploeuc (Moncontour granite) are of a porphyritic grey granite closely resembling Cornish granite. The zircons occur both in a zoned and a clear type, the former predominating by about 30 or 40 to one. The habits are those of the Group II and Bégard granite zircons. Apatite is plentiful and well formed cores of inclusions are common. Sphene and muscovite are present. The Moncontour mass is thus closely allied genetically to the Bégard granite.

The Dinan mass is considerably elongated, being over forty miles long, and like the Quintin granite it is in part foliated. The differences between the mineral suites of the foliated and unfoliated granite are slight, the main difference being that in the foliated material the apatite lacks good crystal outline and central cores of

inclusions are replaced by strings of bubbles. At St. Pierre-de-Plesguen the rock is more basic and the index figure of 21·6 shows dioritic affinities.

A specimen from Mont St. Michel of an acid type of muscovite granite was notable for its content of blue tourmaline with smaller amounts of yellowish-brown tourmaline. The zircons are of a short stumpy type with (311) predominating and closely resembling many of the Cornish Armorican granite zircons.

The western end of the Avranches granite appears to be near the roof and contains abundant cordierite in various stages of decomposition, macroscopic crystals occurring up to about an inch in length. Tourmaline is abundant in the heavy residue of a specimen from the margin of the granite in the quarry just above Avranches railway station, but is absent from a specimen from a quarry at the east end of the town and further from the margin.

Most of the zircons in the Avranches samples are clear, but their habit is dominated by the (311) pyramid and is similar to many Cornish Armorican granite zircons. Apatite is reduced in amount compared with the other granites, but there is some tendency towards the formation of cores of inclusions.

The two specimens collected from the Avranches granite are not as representative of the mass as are the majority of the specimens here dealt with because at Avranches the granite is clearly in an early stage of denudation and that part of it which is exposed is manifestly contaminated—as witness the abundant cordierite and its alteration products—and is also considerably pneumatolyzed. The indications are, however, sufficient to show that it is to be correlated with the other Armorican granites already dealt with.

The S.E. extremity of the granite of La Ferté Macé which is referred by L. Vandernotte (9) to the Vire type and which is clearly in line with the Avranches mass yields apatites without cores. The zircons are of two habits, an elongated and a stumpy.

The specimens examined from the Vire granite, a parallel mass to the north of the Avranches granite, yield heavy mineral suites which agree very closely indeed with those of the Fougères granite to the south. Many of the zircons are elongated and assume a "torpedo" habit. The Vire granite is, on the whole, very similar to the Group I granites.

VIII. Group VII Granites.

The Fougères granite is the only one of this group of which specimens were examined. Specimens of biotite granite taken from around St. James yield biotite, zircon, apatite, sphene and rare monazite. The zircon is perfectly clear and occurs in elongated acicular habits and shorter varieties, all with (311) as the dominant pyramid. The apatite frequently displays cores of inclusions, but they are not well developed. The suite is similar to that of the granites of Group I, but the zircons are devoid of zoning.

Vandernotte (9) has recorded the mineral composition of the gabbros, dyke rocks and granites of the southern part of the eastern border of the Armorican massif, including the granites of Fougères, Lassay, La Ferté Macé, St. Martin, Deux Évailles, Argentré and some other small granite masses. The Fougères and La Ferté Macé masses are the only points of direct contact with the area covered by the present paper. All the granites, except that of Le Pertre, which is unconformably overlain by the Lower Dinantian, are referred to the Vire type, i.e. are similar to the granites of Groups VI and VII, and several of them invade the Lower Devonian.

In the granites and microgranites the principal heavy minerals noted are biotite, muscovite, macroscopic cordierite and its decomposition products, zircon, sphene and secondary epidote. Apatite, rutile, chlorite, andalusite, garnet and pyrites are said to be rare. Thin sections only were examined. The absence of tourmaline, anatase and brookite and the rarity of rutile should be borne in mind. Chemical analyses show a great similarity between all the granites. From these data it is very probable that the mineral suites of these granites are similar to those described by the present writer.

In the case of a syenitic modification of the Ernée granite Vandernotte actually separated the heavy minerals using strong acids, however, in the process. Brookite and a little zircon, anatase and rutile were found. The tabular brookite shows peripheral alteration to rutile. The zircon occurs in both long and short prisms and shows distinct zones of growth. The anatase forms colourless tablets. The brookite is traced into the chalk of the Paris basin (10), where it first appears, over a wide area, in the upper Turonian which is therefore perhaps an important date in the erosional history of the granites of this region.

IX. St. Malo Gneisses, Southern Brittany, and the Lesser Channel Islands.

St. Malo Gneisses.—A further group of granites runs from the eastern end of the Moncontour mass in a north-easterly direction across the mouth of the Rance, through Dinard and St. Malo. They are foliated and are marked on the official map as gneisses and schists of indefinite age. In Fig. 1, however, they are grouped by Barrois with the "Granulite de Quimper", i.e. with the Armorican muscovite bearing granites.

A specimen of granitic gneiss from St. Malo yielded five per cent of biotite and one per cent of muscovite, common sillimanite and zircon, and scarce apatite. The zircons are very small and quite unlike any of the normal Armorican granite zircons, while the scarce apatites display no cores. The suite is quite unlike that of any of the normal Armorican granites.

Southern Brittany.—A specimen of the "granulite" around the Baie de Quiberon from La Trinité-sur-Mer was examined to ascertain

if the Armorican characteristics which have been shown to exist for the heavy mineral suites of the granites of northern Brittany persist in the granites further south. It yielded a suite similar in a general kind of way to that of the "granulites" further north. The two types of zircon were present, although the buff ones showed hardly any attempt at zoning, and the cores of inclusions in the apatites were very imperfect. Monazite with dark inclusions was also present.

Chausey Islands.—In the French official map this granite, together with that of Les Minquiers to the north, is classed as Permo-Carboniferous. Previously in 1885 Les Minquiers were given as "Gneiss Granulitique" and it was stated that the granite of the Chausey Isles "a fait son apparition avant la fin de l'époque cambrienne puisqu'on le trouve en galets roulés dans les conglomérats du sommet de ce système" (11)—expressions of opinion which cannot be reconciled.

The Chausey granite is a grey biotite granite with a little muscovite. Its heavy mineral suite includes zircons of a buff zoned type and a clear variety while its well crystallized apatite frequently contains cores of inclusions. Rare, almost colourless sphene is present. This suite conforms closely to the general characteristics of Groups I, II and IV and approaches most closely to Group IV.

Minquiers.—Three specimens of gneiss were examined from Maîtresse Île, a small island at the extreme eastern end of the Minquiers group. The gneisses contain inclusions of mica-schist and pegmatite veins. The specimens were a fine-grained granitic gneiss, coarse granitic gneiss with a tendency towards augen structure and a grey granite showing only slight alignment of the biotite flakes. These three specimens were at once found to be distinctive in containing abundant magnetite. The zircons were small and had nothing in common with those of the Armorican granites of Brittany, while the apatites were ill developed and a rare tendency towards imperfect cores of inclusions was observed only in the coarse granitic gneiss. The French official geological map gives Les Minquiers as Armorican granite, but there is nothing about the heavy mineral suites to support this. Their occurrence on the prolongation of the Perros granite axis together with the occurrence of magnetite and the character of the zircon and apatite suggest a tentative correlation with this granite.

Ecréhous.—These islands are marked on the French official map as altered Cambrian sediments, but are now known to consist of granitic gneiss (12). The specimen examined of the Ecréhou gneiss was a moderately foliated granitic rock yielding three per cent of heavy mineral of which about two per cent was biotite and a half per cent muscovite. The apatites are not always well crystallized and central inclusions present are only of an opaque type and do not form definite cores. The zircons are all very small and no zoned

crystals were observed. Moreover, the habits of the zircons are foreign to the usual run of Armorican granites. A turbid variety of sphene occurs.

This suite appears to have no connection with the Armorican granites of the mainland and Chausey.

Paternosters.—The rocks of the Paternosters are very similar in general appearance to those of the Ecréhou reef nearly 20 miles away. The index figure and proportion of biotite and muscovite are practically the same as in the Ecréhou material. The characters of the zircon and apatite are also very similar. The Paternosters are thus to be correlated with the Ecréhous and probably also with the Minquiers, although in the last named islands slightly more basic types are present. Mr. Mourant's thin sections also lend support to this correlation. Insufficient material and departure for overseas prevents definite assignation of the St. Malo gneisses, but they may possibly be related to the Ecréhous, Paternosters, and Minquiers.

Herm.—This is a granitic island lying nearly midway between Guernsey and Sark. The specimen examined bore a resemblance to much of the granite around Bégard. The index figure of 12·7 is mainly made up of biotite, but pale green hornblende like that of Bégard is abundant. The zircons fall into two types, a buff partially zoned type and a clear type. The apatite is well crystallized but true cores are scarcely developed. The heavy mineral suite bears some of the characters of the Armorican granites of the mainland, but there are also some differences. On the whole, however, it appears probable that it is related to the general types of Armorican granites occurring in northern and central Brittany and north-west Normandy.

X. Discussion and Summary.

The nearly uniform character of the heavy mineral suites of the Group II granites from l'Aber-Ildut eastwards to Trégastel, Jersey, Flamanville and Barfleur (a distance of about 200 miles) shows that correlation of granites by the method used in this paper is, under suitable magmatic and tectonic conditions, possible over distances of an order which should attach to it considerable importance. These granites are evidently comagmatic. Their age is shown by the intrusive relations of the Flamanville granite to be Post Lower Devonian and Pre-Cretaceous and thus in all probability Permo-Carboniferous. This is further borne out by the almost exact parallelism of strike or general trend of the Group II granites with that of the Permo-Carboniferous granites of Devon and Cornwall. Also by the following mineralogical evidence :—the dominant habits of zircons occurring in the granites of Devon and Cornwall are also the dominant habits in the Group II granites, and while in Devon and Cornwall zoning of the zircons tends in a general kind of way to become progressively more perfect and pronounced towards the east (Dartmoor) a rather similar state of affairs exists in the Group II

TABLE SHOWING DISTRIBUTION OF THE HEAVY MINERALS.

	Locality.	Index Figure.	Zircon.	Buff zoned Zircons.[1]	Apatite.	Do. with cores.	Sphene.	Monazite.	Rutile.	Anatase.	Brookite.	Tourmaline.	Fluor.	Andalusite.	Pinite.	Sillimanite.	Zoisite.	Clinozoisite.	Epidote.	Pyrrhotite.	Pyrite.	Molybdenite.	Muscovite.	Biotite.	Chlorite.	Hornblende.	Magnetite.	Haematite.	Description of Specimens.
Group I	E. of Cléder	11·2	3	+	5	+	3	1	3	.	.	.	.	1	.	.	.	.	.	.	.	.	5	10%	.	.	.	.	Porphyritic.
	Brignogan	6·2	2	+	3	+	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	5	5%	.	.	.	.	,,
	Sibiril	3·0	1	+	5	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	2·5%	.	.	.	.	"Granulite."
	3 km. S. of Brignogan	5·4	3	+	4	+	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	5	4%	.	.	.	.	,,
	Île Grande	3·5	2	+	4	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	3%	.	.	.	.	Normal.
	Île Grande	5·0	2	+	4	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	3%	.	.	.	.	"Granulite."
Group II	Île Melon	16·9	3	+	5	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	15%	.	.	.	.	"Granite Porphyroïde de l'Aber-Ildut."
	Porspoder	5·1	4	+	4	.	.	3	.	.	.	.	2	.	.	.	.	.	.	.	.	.	5	4%	.	.	.	.	
	Argenton	11·8	4	+	4	+	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11%	.	.	.	.	
	Portsall	16·0	3	+	5	+	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15%	.	.	.	.	
	St. Pol de Léon	7·4	3	+	5	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7%	.	.	.	.	
	Carantec	7·6	3	+	5	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7%	.	.	.	.	
	2 km. N. of Pleumeur	7·3	4	+	5	+	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6%	.	.	.	.	
	2 km. S. of Trégastel	2·5	4	+	4	+	.	4	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	
	E. of Trégastel	8·4	4	+	4	+	5	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	
	Jersey	4–16	4	+	4	+	4	.	.	.	.	3	.	.	.	.	1	1	3	.	.	.	.	F	3	5	3	.	Average Newer Granite.
	Diélette	14·4	4	+	5	+	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	F	2	.	Margin \ Flamanville
	Artot	3·1	3	+	5	+	1	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	2	4	2	5	3	.	Centre / Granite.
	Cap Lévy	10·7	4	+	4	+	1	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	10%	.	5	.	.	Barfleur Granite.
	Port de Landemer	12·8	4	+	5	+	3	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	5	F	.	5	.	.	
	Barfleur	13·6	3	+	5	+	5	3	3	2	.	1	1	.	.	.	.	.	.	.	.	.	5	F	3	5	.	.	
	Pte. de Barfleur	5·6	2	+	4	+	.	3	.	.	.	2	.	.	.	.	.	.	.	.	.	.	5	F	2	.	.	.	Granite Dyke.
Group III	Sillon de Talbert	10·2	4	.	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	F	4	4	.	Granite de Perros.
	Bréhat	7·3	4	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	F	.	3	.	
	Perros-Guirec	3·2	4	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	F	.	3	.	
	Kermaria-Sulhard	0·4	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	4	2	.	3	.	
	Channel Islands	0·8	3	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	4	4	.	Average Older Granite.
	Jobourg	12·1	4	.	4	.	.	1	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	5	5	.	.	Jobourg Gneiss.
	W. of Anse du Moulinet	30·0	3	.	5	.	3	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	.	3	
	Anse du Moulinet	5·1	3	.	4	.	2	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	5	5	.	.	.	
	Shore facing Sidman	27·0	.	.	5	.	2	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	5	4	.	
	W. end Anse St. Martin	4·2	3	.	5	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	.	.	.	
	,, ,, ,,	6·6	3	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	.	2	.	
	E. of Anse St. Martin	1·5	3	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	.	3	.	La Hague Massif.
	,, ,, ,,	26·4	3	.	5	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	5	.	.	
	W. end Anse St. Martin	6·3	3	.	5	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	.	.	
Group IV	3·2 km. N.W. of St. Renan	6·4	3	+	2	+	.	2	.	.	.	4	.	2	.	.	.	.	.	.	.	.	4	F	.	.	.	.	Brest Granite.
	3 km. S.W. of Ploulech	3·5	3	+	4	+	.	2	.	3	1	.	.	.	.	.	.	.	.	.	.	.	4	2·5%	.	.	.	.	Porphyritic.
	600 m. N.W. of Bégard	23·3	4	+	5	+	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22%	.	4	.	.	Dark
	,, ,, ,,	10·3	4	+	5	+	3	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	9%	.	5	.	.	Light
	1½ km. W. of Bégard	10·0	4	+	4	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9%	.	.	.	.	Normal } Bégard Granite.
	,, ,, ,,	1·2	4	+	4	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1%	.	.	.	.	Dyke
	1 km. S.E. of Bégard	13·4	4	+	4	+	5	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	11%	.	5	.	.	
	W. Guingamp	8·9	3	.	3	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	7%	.	.	.	.	Guingamp Granite and "Granulite", mostly foliated.
	2 km. W. of Guingamp	0·2	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	2	.	.	.	.	
	2 km. E. of Guingamp	7·6	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	
	8 km. S. of Guingamp	5·6	3	+	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	4%	.	.	.	.	
Group V	St. Brieuc	10·4	.	.	3	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10%	.	.	.	Doleritic "Syénite de Coutances."
	2 km. W.S.W. of Plurien	46·1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	46%	.	.	
	S. of Sables d'Or	30·3	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	28%	.	.	
	Plevenon	22·5	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	20%	.	.	
Group VI	9 km. N. of Quintin	8·4	3	+	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	7%	.	.	.	.	Quintin Granite.
	2½ km. N. of Quintin	4·1	4	+	4	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3·5%	.	.	.	.	
	1½ km. S.E. of Quintin	8·0	4	+	3	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	
	2½ km. S. of Quintin	5·5	3	+	4	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	
	L'Hermitage, nr. Ploeuc	3·9	4	+	4	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3·5%	.	.	.	.	Moncontour Granite (Porphyritic).
	1 km. E. of l'Hermitage	9·5	4	+	3	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	9%	.	.	.	.	
	1 km. W. of Dinan	1·2	2	+	4	+	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	F	F	.	.	.	.	Dinan Granite.
	Carrière du Rouvre	9·8	3	+	4	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9%	.	.	.	.	
	St. Pierre de Plesguen	21·6	3	.	4	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	20%	.	.	.	.	
	1 km. E. of Dinan	16·2	2	+	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	F	.	.	.	.	
	8 km. E. of Mt. Dol	13·4	4	.	5	.	.	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	5	F	.	.	.	.	St. Marcan Granite.
	Mt. St. Michel	.	2	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	"Granulite."
	Avranches (above Stn.)	6·0	2	.	2	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	F	3	.	.	.	.	Avranches Granite.
	Avranches (E. of town)	2·8	2	.	3	.	.	.	.	.	.	5	.	5	.	.	.	.	.	.	.	.	5	4	.	.	.	.	
	10 km. W. of Alençon	.	3	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	F	.	.	.	.	La Ferté Macé Granite.
Group VII	St. James	17·3	3	.	4	+	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15%	.	.	.	.	Fougères Granite.
	2 km. S. of St. James	15·6	3	.	4	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14%	.	.	.	.	
	3 km. S.E. of St. James	13·4	3	+	4	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12%	.	.	.	.	
Miscellaneous	Montviron	15·3	3	.	4	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	13%	.	.	.	.	Vire Granite.
	S. of Vire	17·7	3	+	5	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	15%	.	.	.	.	
	St. Malo	6·6	3	.	2	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	5	5%	.	.	.	.	Gneiss.
	La Trinité-sur-Mer	5·3	3	+	3	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	4%	.	.	.	.	Quiberon "Granulite".
	Chausey	15·2	3	+	4	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	12%	.	.	.	.	Two specimens.
	Herm	12·7	3	+	4	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	5	.	.	Grey Granite.
	Minquiers	6·6	2	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	5	.	Fine Granitic Gneiss.
	,,	7·9	3	.	4	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	5	.	Coarse Granitic Gneiss.
	,,	8·0	3	.	4	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	5	.	Grey Granite.
	Paternosters	3·6	3	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	2·5%	.	.	.	.	Gneissose Granite.
	Ecréhous	3·0	3	.	4	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	2%	.	.	.	.	Gneiss.
	L'Etacq, Jersey	4·2	4	+	2	.	1	.	.	.	.	3	.	.	.	.	.	.	2	.	5	2	.	.	5	.	.	.	Order of increasing contamination.
	Le Pulec, l'Etacq	2·6	4	+	3	+	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	5	.	.	.	
	Le Pulec, l'Etacq	1·0	3	+	.	.	1	.	.	.	.	.	2	.	.	.	.	.	1	.	.	.	3	.	5	.	.	.	

Explanation of Symbols.—1 = rare; 2 = scarce; 3 = common; 4 = very common; 5 = abundant; F = flood. In the case of biotite, chlorite, and hornblende, approximate percentages of total weight of rock are given where possible. + Denotes the presence of buff zoned zircons and apatites with cores respectively.

[1] The buff zoned zircons are in every case in addition to water-clear zircons.

(To face p. 232

granites of Brittany. Those granites of the South-West of England, which contain zoned zircons always have in addition a water-clear type of zircon which every now and then contains included minute zoned zircons, showing that the zoned crystals are of earlier formation. The same phenomenon has been observed in most of the Group II granites.

In a previous paper (1) the writer considered the Jersey " Newer " granites to be most probably Pre-Cambrian. In Jersey there is no direct evidence as to the age of the granites and the writer was led to this opinion by the fact that what may be " Newer " granites in Alderney, have been described as unconformably overlain by Cambrian sediments. The evidence on which this was based was inconclusive for the igneous rocks of Alderney are not all unconformably overlain by sediments. Mr. Mourant has recently found the contact with diorite opposite l'Etac à la Quoire to be a thrust plane and while the contact with porphyry below la Hougue Mill described by Bigot (13) and Plymen (14) appears to be a genuine unconformity it should perhaps be re-examined in view of the doubts recently cast on unconformities at the base of the Cambrian throughout the Armorican Massif (15). The true relation of the " Newer " granites to the sediments is nowhere seen.

The Jersey granites are on the strike line or general trend of granites running from near Brest to Flamanville in Normandy. Comparison of the varietal characters of the minerals of the Jersey " Newer " granites with those of Trégastel to the west and Flamanville to the east shows agreement in such detail as to leave little doubt that they are co-magmatic with the rest of the Group II granites. The Jersey granite differs from the average rather more, perhaps, than any other in Group II but it is very similar to the marginal variety of the Flamanville granite, the age of which is reasonably determinate. The Flamanville granite, moreover, shows a transition, in what appears to be a simple intrusion, from the contaminated or Jersey type to a variety not merely resembling the average of Group II, but lying on the other side of the average and showing affinity with Groups I, IV and VI. The Jersey " Newer " granite may therefore be considered as marking the culminating point of the contamination characterizing the whole group, its unique features being due to the fact that the country rock was largely gabbro. It would be of great interest to discover whether there is a granite in Jersey corresponding to the central variety of the Flamanville granite.

The granites of Groups I, II, IV, VI, and VII are clearly in fairly close genetic relationship and, although the different groups were not necessarily intruded simultaneously, they must have been injected from the same magma reservoir with probably no great interval of time between them—geologically speaking. With the exception of Group II these granites are all grey or bluish grey in the field.

The only direct field evidence of the age of the Group II granites

is given by the intrusive relations of the Flamanville granite (Post-Lower Devonian and Pre-Cretaceous), all other members of this group being intrusive into known or supposed Pre-Cambrian rocks. Barrois (3) has, however, shown indirectly that the Granite Porphyroïde de l'Aber-Ildut is Post-Dinantian. In Group IV the Bégard mass is, at its western end, intrusive into the Lower Devonian. In Group VI the Quintin granite is intrusive into the Lower Carboniferous (Dinantian) as is also the granite of Rostrenen. The Flamanville granite has a Cretaceous outlier resting on it, while the Athis and Briouze-St. Gervais masses, in line with the Vire granite and in all probability of the same age, are unconformably overlain by outliers of the Lias. A Tertiary age for any of these granites thus appears very improbable, the field and mineralogical evidence when taken together being overwhelmingly in favour of a Permo-Carboniferous age for the intrusions.

The majority of the larger granite masses of northern Brittany, Jersey and Normandy (those of Groups I, II, IV, VI and VII) are thus considered to be of Permo-Carboniferous age and to have been intruded in connection with the Armorican folding.

XI. Correlation of Granite Masses by Their Heavy Mineral Suites.

The writer first attempted the correlation of some granite masses by their heavy mineral suites in two papers on the Channel Islands in which it was shown that the " Newer " granites of Jersey were evidently comagmatic and were characterized by a fairly uniform heavy mineral suite which differed from the suites yielded by the other plutonic masses. Since the publication of these papers he has had the opportunity of considering the various arguments expressed by geologists for and against the method. Quite a number, however, prefer to have more evidence available before expressing an opinion. Now that more evidence is being brought forward in the present paper it may not be out of place to make some further observations on the various questions which arise and on the scope and limitations of the method.

The basic idea which prompted this work has been as follows :— Neighbouring granites, if comagmatic, should reflect their relationship in possessing heavy mineral suites with many points in common and this for the reason that such minerals as zircon, apatite, monazite, rutile, iron ores and, sphene, generally crystallize from the magma at an early stage of cooling and thus, in their colour, inclusions, habits and peculiarities, give valuable characteristics dependent on the original composition and early cooling history of the magma. The present paper brings out clearly that this is particularly the case with comagmatic granite masses injected along a common tectonic axis, along which the granitic outcrops may also be aligned. The opposite set of conditions where neighbouring granite masses yield totally

dissimilar heavy mineral suites must not necessarily be taken to indicate age difference although this is probably true in most cases.

Where, as in Brittany, granites of approximately the same age are intruded along neighbouring, roughly parallel, trend lines or tectonic axes, the several members of one particular trend line may be closely similar—as far as heavy minerals are concerned—but may differ slightly from the members of another line. The differences are rather slight and not sufficient to mask the general relationship of one to another. The different belts in Brittany all have a buff, more or less zoned, type of zircon as well as a water clear type with occasional inclusions of the zoned crystals and it is a remarkable fact that the same observation holds good for the English belt of Armorican granites from Dartmoor to Scilly as has been shown by the work of Brammall, Chatterjee, Ghosh, Leech and the writer.

Merely to enumerate the minerals present and to attempt correlation by means of the names of the mineral species is as futile as to attempt accurate stratigraphical zonal correlation when the generic names only of the fossils involved are known. The colour, dimensions, habits, nature of inclusions and any other peculiarities of each mineral have to be carefully noted and compared with those in other specimens. It will be found that the habit or habits of the zircon of any granite mass are fairly, and often very, regular throughout the mass and even when the mass is composite there is often a general community of aspect (as distinct from one particular habit). The degree of variation of habit, dimensions, etc. of the zircons of a particular belt of granites is very difficult to express verbally, but some impression of it may be gathered from Plate XIV which has been specially drawn to illustrate this point. The apatite of granites of different ages crystallizes to different degrees of perfection and the Armorican granites of the area considered in this paper have been found in the great majority of cases to be characterized by cores of included matter (see folding table), the inclusions falling into some five or six types, according to the nature and arrangement of the included matter (5).

For correlation purposes attention should be focussed principally on the primary stable minerals such as zircon, apatite, monazite, rutile, sphene, muscovite, biotite, hornblende, iron ores, etc. Next in importance come the pneumatolytic minerals such as tourmaline, fluor, topaz, cassiterite, etc. and it should be borne in mind that anatase and brookite frequently come under this category, being derived from titaniferous biotite by pneumatolytic action. Irregular distribution of the pneumatolytic minerals is only to be expected.

Less attention need be paid to minerals of the epidote and chlorite groups, these being mostly secondary. Orthite (or allanite) is however an exception, as it indicates the presence of cerium in the magma.

Equally little attention need be paid to those minerals which are clearly due to contamination of the magma by assimilation, such as

andalusite, garnet, cordierite and pinite, etc. In particular cases hornblende, biotite and sphene may be in large measure due to this cause.

The index figure, or percentage weight of the rock exceeding bromoform in density (about 2·8) should be determined in the case of every sample. It is useful for comparison and in this way differentiation and contamination by assimilation are readily detected—even when the worker has not visited the outcrop in the field. There are three ways of determining the index figure: the rock may be weighed before crushing or as soon as it has passed through the sieve or it may be weighed after it has been washed and dried. No amount of care in crushing will completely eliminate the formation of rock flour and powder although by taking suitable precautions it can be kept within small limits. During washing and decantation (resort must not be made to panning for quantitative work) the bulk of the rock flour is removed. Consequently the index figure determined by the first or second method is bound to be slightly lower than that by the third method. It really matters little which method is used so long as it is used consistently and indicated in the results.[1] Provided specimens are fresh there is reason to assume that the loss of rock flour by washing and decantation has a fairly constant effect on the index figure. Moreover, the index figure must be affected more or less to the same extent for all granites whichever method is adopted.

The mineralogical method under discussion occupies far less time than chemical analysis since two specimens can be examined comfortably in a normal working day (using about 100 gm. of crushed rock per specimen). The method may with every advantage be used in conjunction with a study of chemical analyses (if available), thin sections and hand specimens and even a systematic determination of the plagioclases by means of the Fedorov or universal-stage microscope method. Nevertheless, for rapidity with which results may be obtained and because these results are dependent on a combination of physical and chemical conditions the method is unsurpassed for correlation purposes and the writer hopes that other workers may put it to the test in other suitable areas. It is inadvisable first to attempt to compare granites separated by too great a distance. It is better to examine neighbouring granites, say within 20 or 30 miles of one another, and then, having determined the distinguishing criteria, to extend the area under examination. The most important disturbing factor is foliation although slight intrusion foliation has scarcely any effect except perhaps on the apatite. Where comagmatic granites are in part strongly foliated and elsewhere devoid of foliation difficulties will be encountered.

Upon theoretical grounds various objections to the method have

[1] The writer has invariably used the third method.

been raised, among which the following are perhaps the most important.

(1) The heavy minerals of a granite are dependent not only on the original composition of the magma itself, but also on the rocks into which it is intruded.

(2) The habits and characters of the minerals such as zircon, etc., are known to be dependent on the physical and chemical environment at the time of crystallization. Big differences in habit might therefore be expected between a zircon which crystallized near the roof and another in much greater depth.

(3) Why bother with the heavy and accessory minerals at all: are not the characters of the essential minerals more important?

Such objections, particularly the third, naturally make most appeal to those petrologists who have never crushed an igneous rock to investigate its heavy and accessory minerals. It is much to be regretted that this phase of igneous petrology has not everywhere met with the attention it deserves. The questions raised are answered in the following paragraphs which are based on the experience of having crushed and examined 200 specimens of igneous rocks during the past three years.

(1) This question really depends on our conception of the mechanism of intrusion of a plutonic mass. If its intrusion is accomplished entirely by stoping and assimilation then the heavy mineral suite must depend as much on the nature of the country rocks as on the original composition of the magma. Recent work on the granites of Devon and Cornwall clearly shows that the granites did not stope their way into position, but were rather squirted into regions of relatively low pressure. That assimilation of country rocks has taken place is acknowledged but this appears to be merely that which might be expected by reason of the excess of heat possessed by the magma after it had come into position. Modern opinion is trending in this direction and indeed such results are contained in the early part of this paper; the Group II granites in particular, go a long way towards confirming it, in the case of Brittany at least. According to the writer's experience, therefore, the heavy minerals of the normal uncontaminated granite give a very fair representation of the content of minor constituents in the original magma irrespective of the nature of the country rock. It is evident that particular care is frequently necessary in selecting specimens uncontaminated as far as possible. Numerous specially selected specimens have been examined to test the effects of contamination and these have been found to be as follows:—

(*a*) The zircons of the assimilated rock in some cases appear to survive as xenocrysts.

(*b*) Where granite is intrusive into gabbro it may contain hornblende (as in most of the Jersey "Newer" granites).

(*c*) Assimilation of argillaceous sediments increases the production of biotite and sphene in most cases, as at Trégastel and Flamanville.

In the latter case, where comparison was possible, the zircon and apatite were found to be unaltered by the contamination. Andalusite appears to demand special conditions for its formation. Three carefully graded specimens, collected for me by Mr. A. E. Mourant, at L'Etacq, N.W. Jersey, from a granite stoping its way into shale showed a decrease in the amount of the mafic minerals and the gradual production of muscovite as contamination became more severe. The ultimate apophyses of the granite are muscovite pegmatite. Andalusite, which might have been expected, was not observed. The zircons of the "Newer" granite habits and imperfect zoning persists in all three, though with increasing contamination they become less abundant and "foreign" zircons, probably xenocrysts, become more common. It is noteworthy, also that apatite with central inclusions, characteristic of the "Newer" granites, is present in the moderately contaminated specimen and fluor in the most impure. The index figure for normal granite, 50 yards from the contact, is 4·2. This falls to 2·6 and 1·0 with increasing contamination and the number of mineral species is reduced.

(2) Dr. A. Brammall has informed the writer that in the case of the Dartmoor granite there is some slight difference in habit between the zircons of the highest and lowest types of granite exposed. It is already quite clear, however, that this is not a serious factor; nevertheless it should not be entirely overlooked.

(3) The importance of the essential minerals is in no way belittled. The heavy minerals, however, reflect the presence of the minor constituents, which, for correlation purposes, are quite as important as the major constituents. Moreover, the heavy minerals serve as an important index to the early cooling history.

The readiness is not generally realized with which the accessory minerals may be missed by the ordinary thin section. The following examples should suffice to bear this out. Out of 200 thin sections of Dartmoor granite only one or two showed any hornblende yet Dr. Brammall states that specimens of the granite when crushed and separated almost invariably yield some amphibole. The first piece of Land's End granite crushed and examined by the writer yielded a fair amount of dumortierite, a mineral not formerly recorded from that granite. The writer reported hornblende to be abundant in some specimens of granite presented to him whereat the donor, an eminent petrologist, was surprised and said that he had made twelve thin sections from this material and found no trace of hornblende. The writer was able the next day to produce half a specimen-tube full of hornblende from 60 gm. of the crushed rock.

Much has been said in the preceding pages about the similarity of comagmatic heavy mineral suites. It is however possible, by still more exhaustive mineralogical studies, to determine criteria for the discrimination between detritus from neighbouring comagmatic masses as has been done in the case of a number of the Devon and

Cornish Armorican granites (7), (16), (17), (18). Frequently, however, the varietal details do not vary much in a number of the minerals, the differences lying mainly in the proportions of grains of different colours and shapes and in variations in dimensions. Thus in the Dartmoor granite anatase of brown to yellow tint is dominant and shades of blue are common while in the Falmouth mass blue is dominant and brown and yellow shades quite rare. Nevertheless the same habits and colour zoning are present in both.

Berthois (19) has recently examined the heavy minerals of a large number of Breton igneous and metamorphic rocks. He has determined in each specimen the frequency of each of a number of specified types of zircon and tourmaline with the special object of distinguishing between sedimentary suites of igneous and metamorphic origin.

Note on Index Figure.

This term was initiated by Dr. A. Brammall (14). Recently, however, Prof. Shand in his textbook on "Eruptive Rocks" has used the term "Colour Index" denoting the percentage by volume of minerals exceeding 2·8 in density. Although this is nearly the same thing as "Index Figure" the terms must not be confused. It is unfortunate that Shand has also used the term "Colour Index" where he appears to mean the percentage of heavy minerals by weight.

The writer wishes to express his thanks to Mr. A. J. Robinson, M.Sc., and Mr. A. E. Mourant, B.A. for their company in the field, supplying specimens and help in other ways; and especially to Mr. Mourant who kindly undertook the task of critical revision and seeing the paper through the press on the departure of the writer overseas—a task for which his special knowledge of the geology of the Channel Islands and the adjacent parts of France admirably fitted him. Thanks are also due to Prof. Ch. Barrois and the Société Géologique du Nord for permission to reproduce Fig. 1, to Dr. P. K. Ghosh for making the Brush drawings of Plate XV, and to Miss J. P. Thompstone, Mr. D. Baden-Powell, B.Sc., Major N. V. L. Rybot, D.S.O., F.S.A. and Mr. J. P. Warren, B.Sc., for supplying specimens.

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EXPLANATION OF PLATES XIV AND XV.

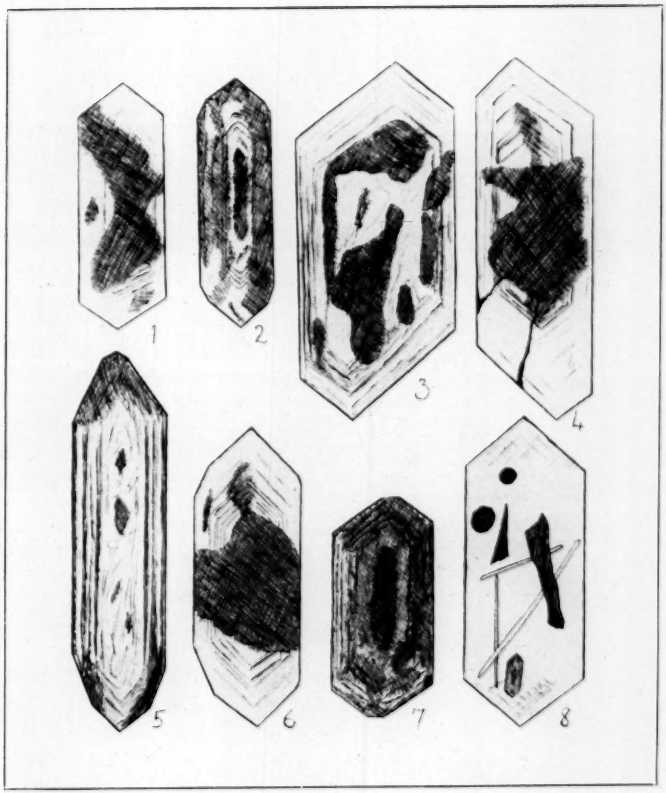
Plate XIV.

Fig.
1.—Île Melon.
2.—Portsall.
3.—Cap Lévy.
4.—Trégastel.
5.—St. Pol de Léon.
6.—N. of Pleumeur.
7.—Carantec.
8.—Trégastel.

Nos. 1 to 7 represent the zoned type, No. 8 the clear.
(See also Nos. 1–4 on Plate XV.)

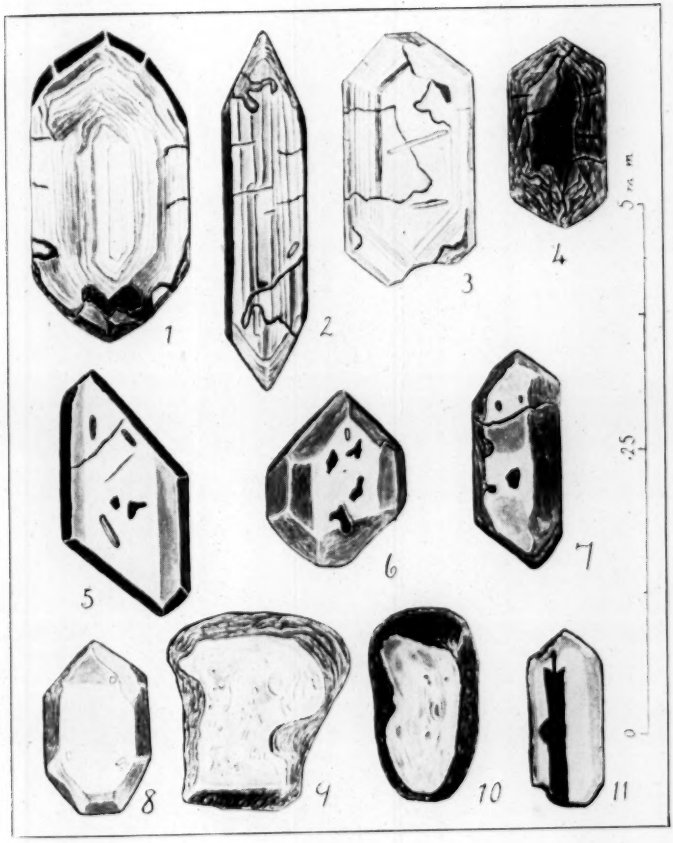
Plate XV.

1.—Zoned zircon. Flamanville.
2.—Zircon, zoned slightly at ends and showing pronounced vertical cleavage. Port de Landemer.
3.—Zoned zircon, Cap Lévy.
4.—Sooty zircon. Cap Lévy.
5.—Monazite with blob-like inclusions and inclusions of zoned zircons. Pointe de Barfleur. a, (100); m, (110); r, (111).
6.—Monazite with inclusions, Cap Lévy. a, (100); m, (110); r, (111); v, ($\bar{1}11$).
7.—Prismatic monazite, Pointe de Barfleur. a, (100); m, (111); r, (111).
8.—Euhedral monazite (rare). Anse du Moulinet. a, (100); m, (110); r, (111); w, (101); x, ($\bar{1}01$).
9 and 10.—Stages in corrosion of monazite.
11.—Apatite with central inclusion. Port de Landemer.



ZIRCON FROM THE GROUP II GRANITES OF N.W. FRANCE, TO SHOW RANGE OF VARIATION. (× 150.)

[*To face p.* 240.



Zircon, Monazite, and Apatite from the Granites of N.W. Normandy.